Stock Assessment Report No. 09-01 (Supplement)
of the

Atlantic States Marine Fisheries Commission

American Lobster Stock Assessment Report for Peer Review

March 2009

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

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American Lobster Stock Assessment Report for Peer Review

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Prepared by the
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Executive Summary

American lobster (*Homarus americanus*) supports one of the most valuable commercial fisheries in the Northeast U.S. with an annual estimated revenue in excess of $372 million in 2007 (Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD). The United States' management unit for American lobster is the Northwest Atlantic Ocean and its adjacent inshore waters where lobster is found from Maine through North Carolina. Canada manages the resource in Canadian territorial waters of the Northwest Atlantic Ocean. The Atlantic States Marine Fisheries Commission (ASMFC) manages the lobster fishery in state waters (0-3 miles from shore) and the National Marine Fisheries Service (NMFS) manages the lobster fishery in federal waters (3-200 miles from shore), both under the authority of the Atlantic Coastal Fisheries Cooperative Management Act. For management purposes, the management unit is subdivided into seven lobster conservation management areas that cut across the three biological stock unit boundaries.

Currently, American lobster is managed under Amendment 3 to the Interstate Fishery Management Plan and its subsequent Addenda, I-IX. The plan is designed to minimize the chance of population collapse due to recruitment failure. The goal of Amendment 3 is to have a healthy American lobster resource and management regime, which provides for sustained harvest, maintains appropriate opportunities for participation, and provides for cooperative development of conservation measures by all stakeholders.

Three stocks units have been identified based on regional differences in life history parameters. They are the Gulf of Maine (GOM), Georges Bank (GBK), and Southern New England (SNE). Each stock supports both an inshore and offshore component, however total U.S. lobster landings are primarily comprised of catch from inshore waters (0 to 12 nautical miles). GOM and SNE areas are predominantly inshore fisheries, while the GBK area is predominantly an offshore fishery. Total landings were relatively constant at about 14,000 mt through the late 1970s. Since then landings have more than doubled, reaching a high of 42,500 mt in 2006. Preliminary landings of 37,200 were reported in 2007.

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

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

SNE has the second largest fishery, accounting for 19% of the U.S. landings between 1981 and 2007. Landings increased sharply from the early 1980s to the late 1990s, reaching a time series high of 9,935 mt in 1997. Landings remained near the time series high until 1999, when the fishery experienced dramatic declines to an average of 2,600 mt between 2003 and 2007. From 2000 to 2007, landings accounted for only 9% of the U.S. landings, reaching a time series low of 6% in 2004.

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

Current abundance of the GOM stock overall is at a record high compared to the 26-year time series. Recent exploitation rates have been comparable to the past whereas recruitment has steadily increased since 1997. The exception is statistical Area 514 which has continued to experience very high exploitation rates and declines in recruitment and abundance since the last assessment. Restrictions are warranted given the persistence of low recruitment and its negative effect on total abundance and egg production potential. Across GOM, effort levels in recent years are the highest observed since 1982 (both in number of traps and soak time) and further increases in effort are not advisable.

Current abundance of the GBK stock is at a record high compared to the 26-year time series and recent exploitation rates are at a record low. Recruitment has remained high in GBK since 1998. Sex ratio of the population in recent years is largely skewed toward females for unknown reasons (~80% from 2005 to 2007).

Current abundance of the SNE stock is the lowest observed since the 1980s and exploitation rates have declined since 2000. Recruitment has remained low in SNE since 1998. Given current low levels of spawning stock biomass and poor recruitment further restrictions are warranted.

This assessment recommends revisions to the set of reference points used in the previous assessment (ASMFC 2006) for management of American lobster stocks (Table 1 below). Revised reference points include median reference abundance and median exploitation rate thresholds for sexes combined over the fixed time period of 1982-2003 in GOM and GBK and 1984-2003 in SNE. The assessment further recommends that stock status be determined by comparing the average reference abundance and average exploitation rate for sexes combined during the most recent three years to stock-specific threshold values.

Based on these reference points, “overfishing” would occur if the average effective exploitation rate during 2005-2007 were higher than the stock-specific median threshold. A stock would be “depleted” if average reference abundance during 2005-2007 fell below the median threshold level. In either of these cases, corrective management action should be implemented.

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

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

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

Table 1. Revised threshold reference points with stock status variables for lobster in each stock area (annual effective exploitation rate and reference abundance in number of lobster).

Variable	GOM	GBK	SNE
Effective exploitation			
Effective exploitation threshold	0.49	0.51	0.44
Recent effective exploitation 2005-2007	0.48	0.3	0.32
Effective exploitation below threshold?	YES	YES	YES
Reference abundance			
Abundance threshold	72,030,500	1,912,355	25,372,700
Recent abundance 2005-2007	116,077,000	4,698,670	14,676,700
Abundance above threshold?	YES	YES	NO

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Terms of Reference

1. Compile data needed for stock assessment purposes including commercial, recreational, discards, and fishery independent data. Update the lobster database to include the most recent information available.

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

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

4. Use the University of Maine model to develop estimates of fishing mortality and abundance for all stock areas. Use Collie-Sissenwine model (CSM) to compare current stock status to prior assessment. Compare performance of the University of Maine model and CSM.

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

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

1.0 Introduction

American lobster (*Homarus americanus*) supports one of the most valuable commercial fisheries in the Northeast U.S. with an annual estimated revenue in excess of $372 million in 2007 (Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD). The U.S. lobster resource occurs in continental shelf waters from Maine to North Carolina. Three stocks have been identified based primarily on regional differences in life history parameters. They are the Gulf of Maine (GOM), Georges Bank (GBK), and Southern New England (SNE) (Figure 1.1). Each stock supports both an inshore (0-3 miles) and offshore (3-200 miles) component; however total U.S. lobster landings are primarily comprised of catch from nearshore waters (0 to 12 nautical miles).

1.1 Management Unit

The management unit for American lobster is the entire Northwest Atlantic Ocean and its adjacent inshore waters where lobster is found from Maine through North Carolina. The Atlantic States Marine Fisheries Commission (ASMFC) manages the lobster fishery in state waters (0-3 miles from shore) and the National Marine Fisheries Service (NMFS) manages the lobster fishery in federal waters (3-200 miles from shore), both under the authority of the Atlantic Coastal Fisheries Cooperative Management Act. The fishery management plan (FMP) is written to provide for the management of lobster throughout their range. The FMP is designed to specify a uniform program regardless of lines that separate political jurisdictions, to the extent possible. The different management authorities are expected to take necessary actions to apply the provisions of this FMP in waters under their respective jurisdictions. For management purposes, the management unit is subdivided into seven lobster conservation management areas (LCMAs) that cut across stock boundaries in many cases (Figure 1.1). Management units do not correspond to stock units defined in this assessment (see section 2.4).

1.2 Regulatory History

The ASMFC American Lobster Board approved Amendment 3 to the FMP in December of 1997. The plan is designed to minimize the chance of population collapse due to recruitment failure. The goal of the amendment is to have a healthy American Lobster resource and management regime, which provides for sustained harvest, maintains appropriate opportunities for participation, and provides for cooperative development of conservation measures by all stakeholders. To achieve this goal, the plan adopts the following objectives:

1. Protect, increase or maintain, as appropriate, the brood stock abundance at levels which would minimize risk of stock depletion and recruitment failure;
2. Develop flexible regional programs to control fishing effort and regulate fishing mortality rates;
3. Implement uniform collection, analysis, and dissemination of biological and economic information; improve understanding of the economics of harvest;
4. Maintain existing social and cultural features of the industry wherever possible;
5. Promote economic efficiency in harvesting and use of the resource;
6. Minimize lobster injury and discard mortality associated with fishing;
7. Increase understanding of biology of American lobster, improve data, improve stock assessment models; improve cooperation between fishermen and scientists;

8. Evaluate contributions of current management measures in achieving objectives of the lobster FMP;
9. Ensure that changes in geographic exploitation patterns do not undermine success of ASMFC management program;
10. Optimize yield from the fishery while maintaining harvest at a sustainable level;
11. Maintain stewardship relationship between fishermen and the resource.

Amendment 3 defines overfishing for the American lobster resource to occur "when it [any stock] is harvested at a rate that results in egg production from the resource, on an egg-per-recruit basis, that is less that 10% of the level produced by an unfished population" (ASMFC, 1997). The primary management measures used to prevent overfishing include a minimum size, protection of ovigerous females, and trap limits.

Amendment 3 established a framework for area management, which includes industry participation through seven Lobster Conservation Management Teams (LCMT). LCMTs were encouraged to develop recommendations for a management program, which suits the needs of the area while meeting targets established in the plan. The Board adopted a three-phase approach to incorporate the LCMT recommendations, which involved three addenda to Amendment 3. Addendum I incorporated measures from the LCMT proposals directed at effort control. After consideration of the stock assessment and peer review results in ASMFC (2000), the Board initiated the development of Addendum II in August 2000 to continue implementation of the 1998 LCMT proposals. Addendum III incorporates the alternative management measures presented to the Board for the purposes of meeting F10% by calendar year 2008.

Addendum IV address four different issues of lobster management: a proposal from the Area 3 LCMT; concern about stock conditions in Area 2; new information about vent selectivity; and a desire to change the interpretation of the most restrictive rule.

American lobster Addendum IV outlines a transferable trap program for Area 3. This program allows Area 3 lobster fishermen to transfer trap tags to other lobster fishermen. Along with other measures, the addendum Area 3 transferability program establishes an overall trap cap and conservation taxes for transferring traps.

Addendum IV includes an interim benchmark goal based on survey information and a Total Allowable Landings to be used as a performance measure. This Addendum includes an effort control program and gauge increases for Area 2.

Addendum IV changes the circular vent size requirement from 2 ½ inches to 2 5/8 inches. In addition, vent sizes of 2 1/16" rectangular and 2 11/16" circular are required for those LCMA's (LCMA 3, 2, OCC) that have scheduled increases to a 3 1/2" minimum legal carapace length.

Addendum IV applies the most restrictive rule on an area trap cap basis without regard to the individual's allocation. Fishermen who designate multiple management areas on their permits are bound by the most restrictive management measures of those areas' trap caps. They are allowed to fish the number of traps they are allocated in that most restrictive area.

Addendum V amends the overall trap cap set by Addendum IV based on comments gathered at public hearings expressing concern that the overall trap cap of 2600 may be too high. Addendum V includes an overall trap cap of 2200 with the higher tax imposed when the purchaser owns 1800 to 2200 traps.

Addendum VI replaces two of the effort control measures of Addendum IV, permits and eligibility period. No new Area 2 permits will be distributed after December 31, 2003 and to qualify for an Area 2 permit endorsement, a permit holder must document landings between January 1, 1999 and December 31, 2003.

Addendum VII establish a multi-state effort control program for Lobster Conservation Management Area 2 that governs traps fished in state and federal waters to cap effort (traps fished) at 2003 levels and allows adjustments in traps based on future stock conditions. The plan limits participation to permit holders who have been active in the fishery in recent years, creates permit-holder specific trap limits that are unique and based on reported traps fished and landings, and establishes a transfer program that allows the transfer of trap allocations with a conservation "tax".

Addendum VIII established reporting and monitoring requirements, which were replaced by addendum X. Addendum X requires at least 10% harvester reporting and 100% mandatory dealer reporting. It also established fishery independent monitoring requirements. Addendum VIII also established new reference points recommended by the 2005 assessment and peer review report.

Addendum IX set a 10% conservation tax for LCMA 2 trap allocation transfers. Addendum XI incorporates rebuilding measures in response to the 2005 assessment finding that the SNE stock is depleted and overfished. It also implements delayed implementation measures which create a species-specific mechanism of ensuring that a state meets its obligations under the plan in a way that minimizes the probability that a state's delay in complying does not adversely affect other states' fisheries or conservation of the resource. Table 1.2 summaries the current regulations used to manage the seven LCMAs.

1.3 Assessment History

The models used to assess American lobster stocks since 1992 (NEFSC 1992; NEFSC 1993; NEFSC 1996; ASMFC 2000) are length cohort analysis, the Collie-Sissenwine (a.k.a. modified DeLury) model, and the life history (a.k.a. egg production per recruit or EPR) model. The Collie-Sissenwine model (CSM) was used to estimate abundance and fishing mortality rates in the stock using landings and bottom trawl survey data. The life history model was used to estimate egg production per recruit reference points such as F10%, the fishing mortality rate that allows female lobster recruits opportunity, on average, to spawn 10% of the number of eggs that would be spawned in the absence of a fishery. The F10% reference point was used, until ASMFC 2000, in lobster stock assessments to determine if overfishing was occurring. Previous stock assessments generally concluded that fishing mortality rates were high for lobster and above the F10% reference point in particular, especially in near shore regions that are heavily fished.

Early in 1996, a Lobster Review Panel was convened by ASMFC and NMFS to provide advice on stock structure, stock assessment, abundance changes, management, and benthic ecology

(ASMFC 1996). The Panel concurred with NEFSC's (1996) conclusion that the lobster resource was overfished (F> F10%) in all areas. The Panel endorsed the stock assessment methods and stock definitions used by NEFSC (1996) and made a number of recommendations for future research and development.

Conclusions and recommendations from the 2000 assessment (ASMFC 2000) were similar to conclusions and results from previous assessments. Overfishing was occurring in all three stock areas (i.e. recent fishing mortality rates > F10%) according to the overfishing definition in the Fishery Management Plan for American lobster (ASMFC 1997). Stock assessment committee members agreed that all three stocks were subject to growth overfishing, the fishing mortality rate that maximizes yield in weight per recruit. At that time, the abundance and recruitment levels were high and the majority agreed that recruitment overfishing was not occurring. At that time, a number of new assessment approaches were investigated for American lobster. A panel of reviewers (ASMFC 2000b) generally supported results and conclusions from the 2000 assessment (ASMFC 2000), but noted serious shortcomings in biological and fishery data used to assess the stock, and recommended further work on new modeling approaches.

In preparation for the 2006 assessment, the American Lobster Stock Assessment Model Technical Review panel (ASMFC 2004) evaluated the CSM model and three new potential modeling approaches for lobster based on simulation analyses. Problems were identified in all three new approaches and shortcomings in biological and fishery data were noted. The review panel agreed that CSM should be used as the primary tool in the 2006 assessment. They noted, however, that estimates of fishing mortality and abundance in absolute terms were difficult to estimate but that trends in abundance and mortality were meaningful on a relative scale. Based on these observations, the reviewers suggested that the assessment should be based on estimated trends to the extent possible.

The 2006 peer-reviewed stock assessment report, which included data through 2003, indicated the American lobster resource presents a mixed picture, with stable stock abundance throughout most of the GOM and GBK, low abundance and recruitment in SNE, and decreased recruitment and abundance in Massachusetts Bay and Stellwagen Bank, (statistical area 514). Of particular concern was SNE, where depleted stock abundance, low recruitment, and high fishing mortality rates had led the Peer Review Panel to call for additional harvest restrictions. One of the short comings of the biological reference points was that the status of each stock is solely based on comparison with a relatively recent 20 to 22-year trend. Trends for a suite of indicators were also examined for the same time period (1982 to present). Abundance of the GOM stock overall was relatively high compared to the 22-year time series. Fishing mortality was low compared to the past. Recruitment and post recruitment abundance for the southern GOM (statistical area 514) declined to historical lows. The GBK stock appeared to be stable; current abundance and fishing mortality were similar to their medians for the 22-year time series. The SNE stock abundance was relatively low compared to the 20-year time series and fishing mortality was relatively high.

The 2004 Model Review Panel recommended that the University of Maine model, a forward-projecting size-based approach that tracks numbers of lobster in a range of size groups by sex, season, and year in addition to estimating yield and spawning biomass per recruit reference points (Chen et al. 2005a), be implemented for the entire lobster stock once the necessary data became available and when analysts could demonstrate sufficient information content in the size data. The 2006 Peer Review Panel also recommended using the University of Maine model because it provides a better foundation for incorporating size composition data from multiple sources simultaneously, capturing the seasonality of the fishery and the lobster life history, and providing a comparable estimate of fishing mortality and reference points. Based on these recommendations the technical committee moved forward in the current assessment using a modified University of Maine model (ASMFC, 2006).

The following report contains summaries of lobster life history, habitat, descriptions of the fishery and fisheries data, bottom trawl survey abundance indices, technical descriptions of improvements to modeling approaches, stock assessment results, an index indicator stock status description, information about overfishing, and recommendations for reference points. The options for new threshold reference points are based on estimated trends, as in the 2006 assessment.

2.0 Life History

2.1 Age

The American lobster is a long-lived species known to reach more than 18 kg (40 pounds) in body weight (Wolff 1978). The maximum age of lobster is unknown because all hard parts are shed and replaced at molting, leaving no accreting material for traditional age determination. All previous assessments have estimated lobster age from per-molt growth increments and molt frequencies. Based on further assumptions regarding lobster molt probabilities, Cooper and Uzmann (1980) estimated that American lobster may live to be 100 years old.

Recent studies conducted in the United Kingdom (UK) have aged European lobster using lipofuscin measurements from neural tissue (Sheehy and Bannister 2002). These researchers have concluded that changes in lobster carapace length (mm CL) explained less than 5% of the variation in true age for 41 European lobster examined over 12 years. Moreover, Sheehy reported that molting was so erratic and protracted that European lobster between 70-80 mm CL required at least five years to fully recruit to legal size (81mm CL) in the trap fishery off the UK (Sheehy et al. 1996). Sheehy's findings suggest that as many as five to eight year-classes, rather than two based on length frequencies, recruit to the European lobster trap fishery each year.

American lobster brain tissue has been isolated and analyzed (Wahle et al. 1996) using a methodology similar to that of Sheehy (1996) for known-age animals up to two years old. Giannini (2007) continued this work using similar methodology for tissue preparation and ImageJ™ v1.32 software, developed by the National Institute of Health, to quantify lipofuscin concentrations for laboratory raised known-age and wild-caught American lobster. Known-age animals, ranging from six months to five years of age (n=49), were obtained from Bodega Bay Marine Laboratory, California, the New England Aquarium, Massachusetts, and from the CT DEP larval lobster survey. Wild lobster were captured in Long Island Sound by Connecticut researchers aboard research and commercial vessels in 2003-2005. Image analysis of the known-age animals showed a significant difference (ANOVA: $F(1,17)=15.65$, $p=0.001$) between mean number of lipofuscin granules located within the olfactory lobe cell mass and age of the individual. Lipofuscin concentration, defined as the collective area of the cell mass occupied by lipofuscin granules, was found to increase with age in laboratory raised animals (regression

r^2=0.75). Variation in lipofuscin concentration among individuals of the same age was smaller than the linear increase in concentration with increasing age, and all six age-classes were statistically distinguishable (SAS GLM Procedure least squares means, $p<0.056$). The results are consistent with other findings for lipofuscin concentrations in wild populations of crustaceans (Sheehy et al. 1995, 1998, Medina et al. 2000, Ju et al. 2003, Kodama et al. 2005, 2006). Applying this relationship to 48 wild-caught animals, ranging from 46-101 mm CL, resulted in predicted ages from 5 to 22 years (Figure 2.1.1) and a very large overlap in size for a given age (Figure 2.1.2). Predicted ages of animals older than that of the laboratory raised known-age animals (i.e. older than age 5) must be viewed with caution, as the accuracy of the power curve extrapolation beyond the age range of the animals determining the curve has not been confirmed. The addition of more known-age animals, especially of older ages, will greatly improve the predictive capabilities of this relationship.

Variability in lipofuscin in animals of the same carapace length can be due to differences in age as well as environmental factors such as temperature (O'Donovan and Tully 1996, Tully et al. 2000). The effect of temperature on lipofuscin concentration rate was not included in the Giannini (2007) study and would be expected to have an effect on the predicted age structure, especially in inshore versus offshore populations. For example, the brain of a wild lobster caught in an otter trawl south of Nantucket, Massachusetts, weighing 23 lbs and measuring 213 mm CL, was analyzed and resulted in a predicted age of 25 years (Giannini 2007). All of the wild-caught animals examined by Giannini were captured from Long Island Sound, minimizing confounding variability due to differing temperature regimes. Even within this fairly homogeneous group, animals one molt-group below the minimum legal size (72-83 mm) represented as many as eight year-classes. This large range in age over a small range of size for lobster just below harvestable size is very similar to the range in age Sheehey et al. (1996) found in recruit-size European lobster, and again highlights the probability that recruitment to the fishery for most lobster populations is far more protracted than the size frequency alone would indicate.

2.2 Growth

American lobster, like all crustaceans, grow incrementally in distinct molting events called ecdysis. Although growth appears to take place entirely during the molt, lobster actually spend much of their lives preparing for, or recovering from, molting (Waddy et al. 1995). Growth rates are affected by two separate components, the size increase per molt, or molt increment, and the frequency of molting. Molt increments are reported as a percent change in carapace length or as the actual change in carapace length per molt. Increments are usually measured from tagged and recaptured lobster or lobster that molted and grew while held in captivity (including those in lobster traps). The frequency of molting is often reported as the probability of lobster at a given size molting in a given year, but is sometimes reported as intermolt duration (the time spent between molts).

The steady state nature of most growth models do not permit growth rates to be linked to variable conditions such as nutrient availability (Aiken 1980, Castell and Budson 1974, Bordner and Conklin 1981, Capuzzo and Lancaster 1979), density of lobster (Stewart and Squires 1968, Aiken and Waddy 1978, Van Olst et al. 1980, Ennis 1991), presence of larger more dominant lobster (Cobb and Tamm 1974, 1975), or variations in temperature (Hughes et al. 1972, Aiken

1977). All of these variables have, however, been shown to influence the frequency of molting and/or the size of molt increments.

In general, the frequency of molting increases with temperature (Aiken 1977). However this increased frequency can be countered by a reduction in molt increment. Blue crabs raised in warmer water were shown to have smaller molt increments (Leffler 1972). Comparison between molt increments of lobster estimated from tagging studies in US offshore waters (Uzmann, Cooper, and Pecci, 1977, Fogarty and Idoine 1988) and those measured in warmer areas (DNC 2008) indicates this also is true of adult lobster. Corroborating evidence comes from continuous seawater temperature readings in eastern Long Island Sound that exhibit a significant increasing trend (slope 0.034°C /yr, $p=0.014$), rising from 1979 to 2007 (see Section 4.1.1). A significant inverse relationship exists between these annual temperatures and the incremental growth of both male ($r=0.50$, $p=0.01$) and female ($r=0.39$, $p=0.04$) lobster (DNC 2008). In addition, summer seawater temperature appears to have confounding effects on growth by decreasing the size at which lobster become sexually mature (Templeman 1936, Estrella and McKiernan 1989, DNC 2008, see section 2.3.1). Mature females sacrifice somatic growth for ovarian growth, and tend to molt on a slower (at least two-year) cycle, extruding eggs and molting in alternate years (Herrick 1911, Aiken and Waddy 1976). Some studies suggest that a proportion of mature females, particularly first time spawners, molt and extrude eggs during the same season (Aiken and Waddy 1976, 1980, Ennis 1980, Ennis 1984, Robinson 1980, Briggs 1985). The overall consequences of these competing temperature related factors affecting the frequency of molting and the size of molt increments in females is that somatic growth is generally slower in warmer regions (see the following two sections).

2.2.1 Molt Probability

Many early studies based on tag recaptures report intermolt duration in terms of molt probability functions (Cooper and Uzmann 1980, Campbell 1983, Campbell and Robinson1983, Fogarty and Idoine 1988, Tremblay and Eagles 1997). Other authors have reported intermolt durations from laboratory data as simply the time spent between molts (Waddy and Aiken 1986). As lobster get larger, there is a declining probability that molting will occur during a year. Estimates vary between studies and often lack data for large (>100mm CL) lobster. Therefore using these functions for modeling growth for the entire population requires extrapolation of intermolt duration, or time spent between molts, for large lobster based on data generated from small lobster. One approach is to use the inverse of the average molt probability at size to calculate an average intermolt duration. However, as the molt probability function approaches zero, the intermolt duration approaches infinity. Because there is no evidence that lobster ever stop molting completely, as some other crustaceans do, this is unrealistic.

The approach used in this assessment was to use the inverse of a molt probability curve to define the maximum average intermolt period at size. Variation in the mean intermolt duration at size was incorporated by using the formula:

$$\text{Year}_{\text{(min-max)}} / (1 / \text{molt probability})$$

where: Year (min) = one for immature females, 2 for mature females
Year (max) = next whole integer larger than or equal to the inverse of molt probability

The size specific annual molt probabilities for the three areas are the same as those described in the 2000 stock assessment (ASMFC 2000), and were calculated from logistic functions with the following parameters:

Stock Area	**α**	**β**
GOM	-8.08127	0.076535
GBK	-6.86700	0.05800
SNE	-9.7200	0.103200

For specifics on intermolt duration calculations for the University of Maine model see section 6.3, growth transition matrices.

2.2.2 Molt Increment

The distribution of potential molt increments is important in modeling lobster growth. ASMFC (2000) assumed that average molt increments were constant (GBK and GOM) or nearly constant (South of Cape Cod Long Island Sound, SCCLIS) for female lobster 55 mm CL or larger. However, these assumptions imply implausibly large average increments (i.e. 11, 13.5 and 10-11 mm in GOM, GBK and SCCLIS, respectively) in lobster as small as 55 mm. A review of growth studies summarized by Fogarty (1995), as well as tag-return studies (Comeau and Savoie 2001, DNC 2008), indicate that molt increments probably depend on size at molting, sex and region. Changes in shell morphology at maturity in both sexes suggest that molt increments may change when lobster become sexually mature (Cadrin 1995). Assumptions about molt increments were revised in the 2005 assessment (ASMFC 2006) to accommodate potential variability among sexes, maturity stages, regions and sizes. Data collected by Maine Department of Marine Resources, Rhode Island Department of Environmental Management and University of Rhode Island, and National Marine Fisheries Service tagging studies were used to generate a “broken stick” relationship where the molt increment increases linearly with size to an inflection point and then is constant thereafter.

The molt increment-carapace length model had three parameters for each sex and region:

$$\hat{I} = \begin{pmatrix} \alpha_{r,s} + \beta_{r,s} L & for\ L < \kappa_{r,s} \\ \alpha_{r,s} + \beta_{r,s} \kappa_{r,s} & for\ L \geq \kappa_{r,s} \end{pmatrix}$$

Where $\hat{I}$ is the predicted increment for an individual in stock/sex group s, $\alpha_{r,s}$ is an intercept parameter, $\beta_{r,s}$ is a slope parameter, and $\kappa_{r,s}$ is an inflection point parameter. Based on this model, the maximum mean increment for lobster larger than the inflection point is max($I_{r,s}$)=$\beta_{r,s}\ \kappa_{r,s}$. The standard deviation of increments given carapace length is important and was estimated from residuals after the model was fit to increment and carapace length data using the Solver function in Excel.

Initial parameter estimates were imprecise, however, because the range of carapace lengths in the data for each sex and region was limited. Several additional assumptions based on lobster biology were made to stabilize molt increment-carapace length model results (Table 2.2.2.1). In particular, the inflection point for females in each area was set at the point where 10% are sexually mature. This assumption reflects the fact that growth changes in female lobster at sexual maturity (Cadrin 1995). The inflection point for males was reparameterized so that $\kappa_{r,Male}=P\kappa_{r,Female}$ where the parameter P=1.16 was the same for all regions and estimated along with other parameters in the model. Similarly, the maximum predicted carapace length for males was reparameterized so that $\max(I_{r,Males}) = J \max(I_{r,Females})$ where J=1.26 was the same for all regions and estimated in the model. Finally, the predicted increment at 6 mm (settlement) was set at 2 mm based on Massachusetts hatchery data (J. Idoine, NEFSC unpublished data). Standard deviations for residuals were similar and ranged 1.7-2.3 mm. For the sake of simplicity, the average standard deviation (2.1 mm) was used for both sexes in all regions.

2.3 Reproduction

2.3.1 Maturity

Size at maturity is related to summer water temperature (Waddy et al. 1995, Little and Watson 2003). Higher summer temperatures enhance maturation at small sizes. Fogarty (1995) reviewed maturity studies that defined geographic differences in size at maturity. Maturation at small size occurs in relatively warm water locations of the Gulf of St. Lawrence and inshore GOM and SNE (Aiken and Waddy 1980, 1986; Van Engel 1980; Estrella and McKiernan 1989, Little and Watson 2003). However, in deeper, offshore waters off the northeastern U.S. and in the Bay of Fundy maturation occurs at larger sizes (Krouse 1973; Campbell and Robinson 1983; Fogarty and Idoine 1988).

Historically, estimates of the proportion of females that mature at different sizes were derived from mathematical functions (logistic curves or maturity ogives) fit to percent maturity at size data. A major shortcoming of this approach stems from management measures that tend to protect mature females from fishing once they reach legal size. Because of such protection the proportions of mature legal-sized females are artificially increased as fishing differentially removes immature females. This result is an inaccurate profile of the proportion mature-at-size above the legal minimum size. For populations with a high percentage of mature sub-legal females (i.e., in SNE), attempts to project a logistic relationship for the entire size range from sublegal sized females have provided unreliable results.

In the 1990s, ovarian dissections were conducted to stage egg development through evaluation of size and color (Aiken and Waddy 1980) to refine the historical maturity. A standard was developed to classify females with egg diameters >0.8 mm as mature. This ovarian staging methodology represents a highly accurate means of evaluating female maturity, but requires the sacrifice of the animal and the developing eggs. An alternative technique, cement gland staging, (Aiken and Waddy 1982) was developed which could be done in the field and did not require the sacrificing of animals. The maturity stage can be quickly and easily assessed by viewing the degree of engorgement of cement glands on the female pleopods. However, this method is only accurate when employed one to two months prior to the spawning season and produces spurious results when used at other times of the year (Waddy and Aiken 2005). Subsequent problems with stage interpretation and regional variability in results, which may have been due to geographic variation in the proportion of females that molt prior to extrusion in a given year, caused the

ASMFC Technical Committee to revert to the more definitive ovarian staging procedure as a standard in 1998.

Maturity ogives for each stock were derived from data on ovarian and cement gland staging of lobster collected from several locations in state waters of Maine (ME), Massachusetts (MA), Rhode Island (RI), and New York (NY). ME and NY studies used ovarian staging while the MA study used cement gland development data which were verified with ovarian staging, and the RI study combined ova stage 4 females with ovigerous females as a maturity index.

All ogives were defined by the logistic function:

$$Pmat_{CL} = 1/1{+}e^{(\alpha + \beta * CL)}$$

Where $Pmat_{CL}$ is the proportion mature at length CL.

The method of calculation of the maturity ogive for each stock is described below. Parameter estimates for the final, average maturity ogives are;

Stock Area	**α**	**β**
GOM	21.210	-0.2320
GBK	18.256	-0.183
SNE	15.276	-0.2061

Gulf of Maine Female Lobster Maturity

In an attempt to account for geographic differences in female lobster sexual maturity within the Gulf of Maine (GOM) stock unit, maturity ogives from different portions within GOM were weighted by landings and combined. Maturity ogives for three regions in the GOM were available. Two were based on ova diameter data collected by the state of Maine (Boothbay Harbor and Sorrento, ME). The third was based on several maturity indicators (D. Pezzack, Department of Fisheries and Oceans, Canada, pers. comm.) and represents the offshore section of the GOM (Brown's Bank, Canada).

Weighting factors were derived as proportions of the 1984 to 1994 mean GOM landings based on combined landings from statistical areas that are representative of where each maturity curve originated. The maturity curve from lobster sampled around Boothbay Harbor, ME was used to represent the inshore southwest portion of the Gulf of Maine, and was weighted with the proportion of landings from statistical areas 513 and 514 combined. The maturity curve from lobster sampled from Sorrento, ME was used to represent inshore northwest portion of the Gulf of Maine, and was weighted with the proportion of combined landings from statistical areas 511 and 512. The maturity curve from lobster sampled from the Browns Bank, Canadian is representative of the offshore Gulf of Maine, and was weighted with the proportion of combined landings from statistical areas 464, 465, and 515. The three weighted curves were then combined to create a maturity ogive representative of the entire GOM. A logistic function was used to fit the combined curve and to obtain alpha and beta parameters (a = 21.210, b = -0.232). The resulting combined maturity ogive is considered representative of the whole GOM stock unit.

Georges Bank Female Lobster Maturity

The maturity ogive for Georges Bank stock was based on ovigerous condition (adjusted for the interaction between growth and extrusion) in lobster collected from northern Georges Bank (Cooper and Uzmann 1977; Fogarty and Idoine 1988).

Southern New England Female Lobster Maturity

In an attempt to account for geographic differences in female lobster sexual maturity within the SNE stock unit, maturity ogives from different regions within SNE were weighted by landings and combined. Maturity ogives were available from five regions within the SNE assessment area. They are as follows; Long Island Sound based on a re-analysis ova diameter data from Briggs and Mushacke (1979), Buzzards Bay based on ova diameter adjusted cement gland data collected by the state of MA, The south shore of Long Island based on ova diameters of lobster collected by the state of NY (Briggs and Mushacke 1980), Block and Hudson Canyons based on ova color (Aiken and Waddy 1982), determined by external observation (without dissection, nor direct observation) from lobster collected by the state of RI., and Coastal Rhode Island Canyons based on ova color determined by external observation (without dissection, nor direct observation) from lobster collected in by the state of RI.

Weighting factors were derived as proportions of 1999 to 2003 average SNE landings based on combined landings from statistical areas that are representative of where each maturity curve originated. The maturity curve from lobster sampled in the southern New England canyons was weighted with the proportion of landings from statistical area 616 and 537 combined. The maturity curve from lobster sampled in Buzzards Bay, MA was weighted with the proportion of landings from statistical area 538. The maturity curve from lobster sampled in inshore RI waters was weighted with the proportion of landings from statistical area 539. The maturity curve from lobster sampled in Long Island Sound (CT data) was weighted with the proportion of landings from statistical area 611. The maturity curve from lobster sampled from the ocean side of Long Island, New York was weighted with the proportion of landings from statistical 612 and 613 combined. The five weighted curves were then combined to create a maturity ogive representative of the entire SNE. A logistic model was fit to the combined curve and to obtain alpha and beta parameters (a = 15.276, b = -0.206). The resulting combined maturity ogive is considered representative of the whole SNE stock unit.

2.3.2 Fecundity

Several studies have reported lobster fecundity at size for various locations throughout the range of the species. The earliest work reported was for the Buzzards Bay and Vineyard Sound areas of Massachusetts (Herrick 1896). Lobster fecundity has been described more recently for sites off Newfoundland (Ennis 1981), the Bay of Fundy, coastal southwestern and eastern Nova Scotia and Northumberland Strait (Campbell and Robinson 1983), coastal Maine (Personal Communication, Kevin Kelly, Maine Dep. Marine Resources, Unpublished Data), the offshore canyon areas of the northeastern U.S. (Perkins 1971), coastal Massachusetts (Estrella and Cadrin 1995), and Long Island Sound (Graulich 1991). Saila et al. (1969) published fecundity estimates of combined samples taken from coastal Quebec, Massachusetts, and Rhode Island. Considerable variation in lobster fecundity at size has been reported for different areas (Ennis 1981; Graulich 1991; Estrella and Cadrin 1995). Squires (1970) postulated that fecundity varies with geographic location. Variation between studies can also be due to differences in collection and/or counting techniques, sample size, and seasonal timing of study.

Estrella and Cadrin (1995) performed extensive analyses on size-fecundity relations reported from Ennis (1981), Campbell and Robinson (1983), and their own samples collected from three Massachusetts coastal regions in 1987-88 (southern Gulf of Maine, outer Cape Cod, and Buzzards Bay). Southern Gulf of Maine estimates were significantly lower than those from the other two Massachusetts areas. Outer Cape Cod was not significantly different from Buzzards Bay. Size-fecundity relations from some Massachusetts regions were statistically equivalent to those from some Canadian areas. The authors reported that although geographic variation in fecundity could not be ruled out, other factors, such as interannual differences in temperature and other environmental variables, and differing methods of collection and handling which contributed to egg loss, confounded definitive conclusions about geographic differences. These authors also performed a rigorous comparison of the historical fecundity data of Vinal Edwards as reported by Herrick (1896) with their own data from southern Massachusetts and found the two sets of fecundity estimates to be nearly equal. Herrick sampled significantly more lobster (n=4,645) than in any recent study and covered a broader size range (66-170 mm CL). Predicted egg numbers, estimated from a power curve fit to Herrick's data, range from 16,870 at 100 mm CL to 222,733 at 200 mm CL. Fecundity estimates (*f*) at length (*L*= mm CL) for all three stock areas in this assessment were based on Estrella and Cadrin's (1995) analysis of Herrick's data:

$$f = [0.0009198 * L^{3.58022}] + 1.09886$$

2.3.3 Sperm limitation in commercially exploited crustaceans

In recent years the sex ratios observed in both fishery-dependent and fishery-independent monitoring programs for the Georges Bank stock have become increasingly skewed toward females. The reasons for these changes in sex ratios are not known. One compelling argument is that the changes in sex ratio are related to the additional protection ovigerous and v-notched female lobster are afforded as compared to males. Protecting ovigerous female lobster and v-notched lobster (known spawners) is a long-standing common sense technique to ensure the sustainability of American lobster stocks. However, the long term consequences of this additional layer of protection to only the female portion of the population are not well understood.

Regardless of the cause, the effects of these changes in population structure could lead to sperm limitation and ultimately disrupt the reproductive potential of the stock. While sperm limitation has not been documented in American lobster, observations of these highly skewed sex ratios (> 80% female) are relatively recent. As such, an examination of recent research in other commercially exploited crustaceans with similar mating strategies provides a useful context for the issue.

American lobster, like many decapods, has a polygynous mating system, where a single male mates with multiple females. Cobb (1995) suggested that American lobster exhibit the mating strategy referred to as "resource defense polygyny" (Emlen and Oring 1977, Krebs and Davies

1993) where a male's relative social dominance appears to be correlated to his mating success. Females exhibit mate choice in this type of mating system by mating with the dominant male, and this male is capable of attracting and inseminating multiple mates. The assumption that has arisen from polygynous mating systems is that sperm are plentiful and eggs are the limiting resource, thus females should be protected from harvest. This has typically been the case in management of crustacean fisheries, with the purpose of protecting the spawning stock. However, researchers have begun to question the assumption of plentiful sperm, particularly in several of the male-only crab fisheries of the Pacific Northwest and the Chesapeake Bay blue crab fishery. There is now a growing body of work examining the male role in the reproductive output of several species, and trying to understand the potential for and implications of sperm limitation in these fisheries.

Sperm limitation occurs when the amount or quality of sperm received by females is insufficient to fertilize the entire compliment of potential eggs. This could happen when there are an insufficient number of mature males, or when the males that are available cannot (or do not) provide enough sperm to their female partners. Specifically, if the sex ratio is too female-skewed, and/or the mature males present are all relatively small, the potential for sperm limitation exists.

Reduced reproductive output by small males relative to large males has been documented in several commercially important species, including blue crabs (*Callinectes sapidus*, Kendall *et al.* 2001), spiny king crabs (*Paralithodes brevipes*, Sato *et al.* 2005), snow crabs (*Chionoecetes opilio*, Sainte-Marie *et al.* 2002), and spiny lobster (*Jasus edwardsii*, MacDiarmid and Butler 1999). This reduced capacity in smaller males has been shown to impact the fecundity of their female partners, in smaller clutch sizes (*Panulirus argus* and *J. edwardsii*, MacDiarmid and Butler 1999) and reduced fertilization rate (*P. brevipes*, Sato *et al.* 2005).

Males are capable of mating with multiple females, but there may be limits to this ability in terms of the time frame involved and complicated by the size of the male. In a laboratory study of *C. opilio*, a decrease in male:female sex ratio resulted in higher sperm depletion rates of males (Rondeau and Sainte-Marie 2001). The order in which female *J. edwardsii* were mated with individual males was related to the weight of the clutch produced by the female (MacDiarmid and Butler 1999). Male *C. sapidus* mating consecutively with two females experienced reductions of 70% in the sperm content of their vas deferens, and took at least nine days to show recovery (Kendall *et al.* 2001). Female *C. sapidus* mated later in a sequence by an individual male received less ejaculate (Wolcott *et al.* 2005) and had reduced success hatching their clutch relative to females mated early in the sequence (Hines *et al.* 2003). Sato *et al.* (2005) showed that male *P. brevipes* just above minimum legal size, "small males, 70 – 90 mm CL" were less capable of successfully fertilizing multiple females than larger males (>100 mm), and the smallest group of legal-sized males were not able to completely fertilize even their first female's clutch. The spawning success and fertilization rate of female clutches was negatively impacted by male mating frequency, and the recharge rates of sperm in the vas deferens of male *P. brevipes* was extremely slow (>28 days, Sato *et al.* 2005).

There is field evidence to support the results of laboratory studies suggesting sperm depletion in wild polygynous males. Kendall *et al.* (2001) showed that male *C. sapidus* collected from

Chesapeake Bay during mating season had low vas deferens weights, similar to or less than that of ‘depleted’ males in laboratory experiments. Additionally, 77% of females collected had spermathecal loads equivalent to the ejaculate delivered by ‘depleted’ males, while only 11% had loads representative of ‘fully recovered’ males (Kendall *et al.* 2002). Male *P. brevipes* collected from a fished population had significantly depleted sperm counts at the end of the one-month reproductive season, and this depletion was more pronounced in small males (Sato *et al.* 2005).

Fishery-induced alterations of sex ratios and size distributions may produce conditions in crustacean populations that could lead to sperm limitation. In a population of *C. sapidus* in Chesapeake Bay, the quantity of ejaculate stored in females’ spermathecae declined over a time period during which fishing pressure increased and stock abundance declined (Hines *et al*. 2003). Females from this population had significantly lower seminal receptacle weights than females in a Florida population that experienced less intensive fishery pressure (as well as more optimal environmental conditions). However, seminal receptacles in the Chesapeake females at the beginning of the time series were similar in weight to the “full” receptacles observed in the Florida population, indicating that Chesapeake females used to receive a full complement of sperm prior to the decline (Hines *et al*. 2003). Sato *et al*. (2005) documented an alteration in sex ratios and size distributions resulting from changes in fishery regulations on *P. brevipes*. Males were less numerous and smaller after the implementation of a male-only fishery with a reduced minimum legal size, while female relative abundance and size distribution remained unchanged. This population structure, combined with laboratory results, led Sato *et al*. (2005) to conclude that sperm limitation is possible in the *P. brevipes* population. Similarly, the reproductive success of *Hapalogaster dentata* (stone crab) could be negatively affected by fishery-induced alterations in sex ratio and decreased male size (Sato and Goshima 2007). The banning of fishing in 1990 on a component of the *Palinurus elephas* (red lobster) population in the western Mediterranean (Columbretes Islands Marine Reserve) appears to have increased size-specific female fecundity, possibly related to the increase in abundance of large males relative to a nearby fished population (Goñi *et al*. 2003).

Females of many species are capable of storing sperm in their seminal receptacles (spermathecae) for extended periods of time. Stored sperm acquired from a single mating can be used to fertilize multiple clutches of eggs by *Chionoecetes bairdi* (Paul 1984), *C. opilio* (reviewed in Sainte-Marie *et al.* 2008), *H. americanus* (Waddy and Aiken 1986), *C. sapidus*, and *Cancer magister* (Smith and Jamieson 1991), among others. However, the degree to which a female can supply her subsequent clutches with adequate sperm may be related to the quality of the male that provided the sperm. In *C. magister*, females that produced clutches fertilized with stored sperm had reduced fecundity relative to females using freshly acquired sperm (Hankin *et al.* 1997). During periods of female-skewed sex ratio in *C. opilio* populations, females do not acquire enough sperm to thoroughly fertilize additional clutches, while during male-skewed periods they have enough stored sperm to produce multiple clutches (Sainte-Marie *et al.* 2002). Additionally, small males provide less seminal fluid than larger males (Sainte-Marie and Lovrich 1994, Sainte-Marie *et al.* 2002), which is also the case in *C. sapidus* (Kendall *et al.* 2001). Seminal fluid is thought to play a role in the viability of stored sperm (Wolcott *et al.* 2005), so when large males are rare and small males are more involved in mating, sperm viability over time may suffer, reducing fecundity.

The issue of sperm limitation in American lobster populations has only recently received attention. Gosselin *et al.* (2003) documented a relationship between both male and female size and seminal receptacle load in mating experiments, but found no relationship between seminal receptacle load and mating order. An added complication, particularly in SNE, is the potential that shell disease may impact reproductive success. There is some evidence that lobster with shell disease exhibit alterations in behavioral patterns compared to non-diseased lobster (Castro et al. 2005), and that diseased lobster sometimes experience difficultly molting (Bradley Stevens, University of Massachusetts, Dartmouth, personnal communication), either of which could alter or disrupt mating behaviors. Additionally, Comeau and Benhalima (2007) documented damaged follicle cells and deformed spermatozoa in the reproductive tract of male lobster in Canada that had shell disease, although it was unclear if the shell disease directly caused the damage.

There are potential alleviating mechanisms in American lobster, such as intermolt inseminations (Waddy and Aiken 1990) and the ability to inseminate multiple clutches with a single spermatophore (Waddy and Aiken 1986), however, the extent to which either of these occur in natural populations is unknown. Additionally, there is genetic evidence that females will mate with more than one male, and that these females were smaller than females with clutches fertilized by a single male (Gosselin *et al.* 2005).

The mating system of lobster (and many other crustaceans) is relatively complicated, and the research discussed above indicates that the reproductive potential of a population can be impacted by the contribution of both males and females. Controlled experimentation and field studies are necessary to understand how both sexes contribute to the overall egg production in American lobster.

2.4 Stock Definitions

In the 2006 Assessment (ASMFC 2006), the boundary between the Georges Bank and Southern New England stocks was changed based on lobster distribution and abundance, patterns of migration, location of spawners, and the dispersal and transport of larvae. Georges Bank was recognized as a unique stock area separate from other offshore areas, and the offshore areas south of Cape Cod were linked with the inshore areas of Southern New England. GBK replaced the Georges Bank and South (GBS) stock, and SNE replaced the South of Cape Cod and Long Island Sound (SCCLIS) stock in the 1996 and 2000 assessments (ASMFC 2000, NEFSC 1996). This assessment used these stock boundaries as developed in the 2006 assessment. Stock definitions are described in terms of bottom trawl survey strata in Table 2.4.1 and in terms of statistical areas used to report landings in Table 2.4.2, and are mapped in Figure 2.4.1.

2.5 Natural Mortality

All assessment models are sensitive to the values chosen for natural mortality (M) and to the interaction between M and other parameters (Vetter 1988, Bannister and Addison 1986). Uncertainty in the nature of M for American lobster is compounded by the fact that aging techniques have not yet been fully developed and employed to determine a reliable maximum age for inshore and offshore stocks (see section 2.1). For this reason, previous assessments have adopted the convention of holding M constant over time and among all size and age groups (Quinn and Deriso 1999). A constant M is usually chosen using some life history criteria such as longevity, growth rate, and age at maturity (Hoenig 1983, Pauly 1980). American lobster's many traits fostering a relatively long life span and slow reproduction have led to the species' classification as "k-selected" with low natural mortality after the larval stage. A low and stable natural mortality rate seems reasonable for American lobster inhabiting stable environments in offshore canyons where they can attain very large size (>190 mm CL, Thomas 1973). A value of $M = 0.15$ was assumed for all recruit and legal size lobster in previous assessments (Fogarty and Idoine 1988, NEFSC 1993, 1996). The same convention was applied in the previous stock assessment (NEFSC 2006) except for SNE where there is evidence of an increase in natural mortality during recent years.

A low and stable natural mortality rate is less certain for lobster stocks south of Cape Cod where environmental fluctuations often can be highly stressful and selective pressures may favor earlier reproduction over a shorter life span. There is a growing body of evidence (Lapoint et al. 1989) demonstrating that natural mortality may be under direct control of biotic and abiotic factors (Sparholt 1990) and/or density-dependent factors (Vetter 1988, Addison 1986, Munro 1974).. Disease outbreaks can produce significant losses in all life history stages (Bayer et al. 1993, Stewart 1980). A widespread die-off of lobster in Long Island Sound in the fall of 1999 caused the Secretary of Commerce to declare a commercial fishery failure in the Sound in January 2000. Research conducted by the University of Connecticut (Mullen et al. 2004) indicated that a protozoan parasite, *Neoparamoeba pemaquidensis*, was the immediate cause of the die-off. This parasite is known to be present in marine waters from the Gulf of Maine to Long Island Sound prior to the 1999 die-off (Gillevet and O'Kelly 2003), however the virulence of the disease was increased by high water temperatures in concert with hypoxia and possibly other environmental factors (Balcolm and Howell 2006).

The severe mortality event experienced by the Long Island Sound lobster population in 1999 was followed by events of lesser magnitude in the following years, and may be an example of how a boreal species is affected by climate warming at the southern boundary of its range. In the summer of 1999, bottom water temperature exceeded the stress threshold temperature (20.5°C or 69°F, see section 4.1) for a total of 83 degree-days. In order to better quantify the relationship between the area of the Sound exceeding 20.5°C and lobster abundance, a statistically rigorous Objective Analysis was applied to four temperature data sets. The analysis generated year-specific weighted matrices by depth strata for the entire Sound in two-day intervals for 1988-2007 (O'Donnell et al. 2008). The sum of the area exceeding 20.5°C was treated as a 'stress index' for each year, and showed a positive slope over the 20-year time series (Figure 2.5.1). The median value for the second decade was 69% higher than the median value for the first decade. A two-year running average, computed to bracket possible chronic temperature effects and minimize single year anomalies, showed a negative relationship with the average of spring and fall lobster abundance indices generated from the CT DEP Trawl Survey from 1997-2007 (Figure 2.5.2). Increasing water temperature trends have been documented throughout the range of the southern New England lobster stock (Figure 2.5.3). Temperatures on Georges Bank show no trend, while temperatures in the Gulf of Maine show smaller increases (Figure 2.5.4).

In light of this widespread change in habitat suitability for the southern stock, as well as the documented mortalities in Long Island Sound, alternate runs of the assessment model were generated for the Southern New England stock using a 50% (M=0.225) and 100% (M=0.30) increase in value of natural mortality in recent years 1998-2007.

2.6 Shell Disease

Shell disease is caused by external bacteria that digest the minerals in a lobster's shell. Since lobster routinely clean themselves, the disease occurs most commonly on the back carapace and claws where they can't easily reach. The suite of bacteria causing shell disease in the wild is the same from Maine to New York (Chistoserdov et al. 2005). Calculating a mortality risk associated with shell disease is difficult. Lab studies have shown that lobster with shell disease can heal themselves by molting out of the diseased shell and replacing it with a new healthy one. However, if the disease bacteria become thick enough to penetrate completely through a lobster's shell, then internal lesions leading to a compromised immune system or death may occur. Ecdysone, a hormone that controls the molting process in lobster, has been found at levels well above normal in shell diseased lobster, indicating that severe cases of the disease may interfere with normal molting (Laufer 2005). An increase in shell disease prevalence may be an indication of above normal stresses in the lobster populations. Since the disease is most prevalent and most severe in eggbearing females, premature molting may cause undetected declines in reproductive success and egg survival.

Shell disease prevalence has been monitored with increasing intensity over the past 25 years. Biologists in the states of New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine record the occurrence of shell disease in lobster examined during commercial sea sampling. Connecticut, Rhode Island, and Maine biologists also record prevalence in lobster captured in their research trawl surveys. The longest monitoring program began in 1984 by biologists studying the lobster population in the area surrounding Millstone Power Plant in eastern Long Island Sound (DNC 2008). The first record of the disease in that area was in 1988, while CT DEP monitoring in eastern LIS first recorded the disease in 1992. Prevalence has increased since the late 1990's in all state waters from Massachusetts south to New York, affecting up to 30% of observed animals in some years (Table 2.6.1 and figure 2.6.1). New Jersey has no monitoring program, however fishermen have reported very little incidence of disease in that state, and western Long Island Sound prevalence has never exceeded 1% of the observed catch. New Hampshire began a monitoring program in 2001 and diseased lobster have also represented a very small percentage (< 0.2%) of the observed catch. Shell disease was noted for the first time in Maine in April 2003 during Maine DMR field observations. During the 2003 and 2004 sampling season, 93 lobster were recorded as having shell disease, which represented less than 0.05% of lobster examined by Maine DMR staff. The largest number of shell-diseased lobster were observed during a sea sampling trip in the June 2004 when 22 of 426 lobster measured (5%) were scored as having shell disease. Shell-diseased lobster were 0.02-0.11% of the catch annually observed by Maine DMR staff in 2005-2007 for all three statistical areas (Table 2.6.1).

3.0 Fishery Description

3.1 Brief history of the lobster fishery

American lobster is often mentioned in documents about New England colonies as an abundant species and a dependable source of bait and food. Wood (1635) commented on lobster abundance that "their plenty makes them little esteemed and seldom eaten". Numerous citations indicate that lobster were easily captured in Canada and New England and were used for food, bait, and fertilizers. Early fisheries were conducted by hand, dip net, and gaffs in shallow waters along the shoreline (Nicosia and Lavelli 1999). Lobsters were also taken in a labor intensive fishery using hoop nets along the shoreline. Wooden lath traps became the dominant gear by 1840. Early vessels were row boats or powered by sail. The use of gasoline powered engines started around 1905.

Rathbun (1887) described the lobster fishery as beginning around 1800 along the coast of Massachusetts, in particular on Cape Cod and near Boston. The initial fishery supplied large lobster (> 3 lb) for the fresh market located in New York and Boston. The fishery was conducted in shallow, near-shore areas. Smack boats cruised the coast catching lobster and/or buying lobster from local fishermen and would carry the catch to Boston and New York Markets. When declining catch rates lobster were unable to supply the markets, the fishery expanded to New Hampshire and Maine waters in the 1840s. A second market for "small" lobster (between 2-3 lb) for canning developed in Maine. Canning began in 1843 and twenty three canneries were operating in Maine by 1880. In 1855, market lobster were 3 lb or greater, culls for the cannery market were between 2 and 3 lb, and lobster less than 2 lbs were discarded. Rathburn reported the following "average" size, in total length, at the four principle markets for lobster in the early 1880's:

Portland, Maine	10.5" TL	(92 mm CL)
Boston, Massachusetts	11-11.5" TL	(97-101 mm Cl)
New Haven, Connecticut	10.5" TL	(92 mm CL)
New York, New York	10.5-15"	(92-133 mm CL)

From 1870 to 1880, the lobster fishery experienced declines in catch per trap and average size of lobster. The fishery responded by expanding the area fished, increasing the number of traps set, extending the fishing season, and fishing single traps instead of trawls in order to cover more area. As average size of the catch declined, markets adjusted by lowering the size of acceptable lobster. Similar trends occurred throughout the range of the lobster fishery. In Buzzard Bay (SNE stock), lobster averaged 3 lb (approx 120 mm carapace length) in 1840 and 2.5 lb in 1880. Today, an average lobster landed from Buzzards Bay weighs 1.18 lb.

A comparison of length frequency also confirms that size structure in the inshore waters was wider in the 19th century than today. Length frequency of lobster captured in Buzzards Bay (Woods Hole) in 1894 and 2002 and length frequency of ovigerous females taken from Vineyard Sound/ Coxes ledge in 1894 and Buzzards Bay in 2002 are shown in Figure 3.1.1. Despite concerns about declining size of the catch in the 19th century, the size structure in 1890's was much broader in Buzzards Bay than is found today.

The decline in lobster landings coast wide led states to implement minimum sizes and closed seasons. The decline of the fishery seen in Massachusetts' waters spread coast wide. The New Jersey fishery was carried out extensively in the 1860's, but was nearly wholly abandoned as unprofitable by 1870, despite proximity to the largest lobster market in New York. Even with indication of a revival in 1872, the lobster fishery in New Jersey remains small to the present time. The fishery in New York and Hell's Gate was also extensively carried on before becoming abandoned due to unprofitable fishery conditions. The Provincetown fishery was abandoned except for men that were too old to participate in alternative fisheries. Large decreases in landings, catch rate, and average size was noted in Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine.

The decline caused the implementation of a series of management regulations in Maine (78.9 mm carapace length April 1 to August 1, remainder of year 92.3 mm, closed season August 15-October 1), New Hampshire (92.3 mm), Massachusetts (92.3 mm, closed season June 20-Sept 20), Rhode Island (87.8 mm), Connecticut (87.8 mm), and New York (92.3 mm). Maine also instituted protection on berried females.

Landings, average size, and catch per trap continued to decline over the next twenty years in all states and Canada. In Massachusetts, the number of lobster (> 92mm) per trap declined from 80 per trap in the early 1880's to approximately 30 per trap in 1907. Concerns about the growing crisis in the fishery led to a Convention in 1903 to develop recommendations for uniform legislation in states to protect lobster. Representatives from Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Canada attended. Lobster stocks were considered to be in critical state with declines in average size of the catch and catch per trap haul. Management measures under consideration were increases in minimum size, slot limits, gear modifications to change selectivity, closed seasons, trap limits, v-notching protection for females, limited access to permitted fishermen only, and hatchery stock enhancement through hatchery propagation. The slot limit was advocated to increase egg production by protecting the larger, more fecund lobster. Protection of berried females and prohibition of landing shelled lobster meat were enacted.

The Convention of 1903 failed to establish uniform regulations because of a concern to tailor regulations to meet local conditions. Enforcement of existing regulations was considered to be problematic everywhere. Scientists also noted the inadequacy of landing statistics. In general, scientists believed that stock declines were fishing related and landings increased with effort, technological improvements, and spatial and temporal expansion of the fishery. The comparative impact of fishing mortality and natural mortality rates through predation and disease on abundance was debated.

States responded to the crisis in various ways. Rhode Island and Massachusetts dropped the minimum size to 78.9 mm carapace length, Connecticut raised the minimum size from 78.9 mm to 79.3 mm. In 1907, Maine increased the size limit to 4.75" total back shell. From 1907 onward, states implemented many small changes in the minimum size, protection for ovigerous females, and prohibition on landing lobster meat. Maine instituted a maximum carapace length. Voluntary v-notching programs were enacted in Maine and Massachusetts.

Landings remained low, averaging approximately 5,000 tons (t) from the 1920's through 1940's. Total landings increased slowly from 1940 through 1970, averaging near 14,000 t through the late 70's. Landings have since doubled and are near 37,000 t in recent years. Landings from the offshore areas were generally taken by otter trawl vessels and were generally less than 50 t through 1946. The offshore trap fishery intensified after the mid-1960's with 2,500 t landed from the offshore canyons in 1965. The deepwater trap fishery has dominated the offshore landings since 1972and catches had a size distribution of lobster that was much wider than the inshore fishery. Skud (1969) concluded that, "canyons that were more heavily fished had lower catch per trap and a smaller mean size". He also reported that the modal size of lobster from Veatch and Lydonia Canyons was smaller in 1965-67 than in 1956 and the decrease in size was greatest in Veatch Canyon. The length frequency of lobster in Hudson Canyon was similar to Veatch Canyon in 1965-1967.

Several conclusions can be drawn from reviewing lobster history. Large lobster were found in inshore shallow water throughout the range of the lobster. Declines in size structure and catch per trap that occurred in the 1880's were attributed to increased fishing effort throughout the range of the fishery. These declines were initially local (Boston- Provincetown) and then spread coast wide. Terms such as commercial extinction were in use in 1903. Low productivity, as measured by landings, extended for long periods; coast wide landings declined over a 25 year period from 1889 to 1915 and remained low for another 30 years. The debate about relative importance of fishing and other factors such as predation and degraded habitats was well established at the turn of the 20th century. Echo's of that debate remain today.

Most of the current management measures under consideration today (minimum sizes, v-notching, closed season, maximum size, slot limits, trap limits, protection of ovigerous lobster) were either discussed or implemented over 100 years ago. In many cases, regulations such as minimum sizes and closed season are less restrictive today than 100 years ago. Arguments about the merits of uniform measures were countered by the need to tailor management measures to meet local needs. With the exception of private property rights, resource managers from the late 19th-early 20th century would be familiar with scientific, social-economic, and political arguments present in decision-making process for managing lobster today.

3.2 Current Status

3.2.1 General

The U.S. lobster fishery is conducted in each of the three stock units; the Gulf of Maine, Georges Bank, and Southern New England. Each area has an inshore and offshore component to the fishery, with the inshore fishery dominating in the Gulf of Maine and Southern New England, and the offshore fishery dominating in the Georges Bank stock unit. The Gulf of Maine supports the largest fishery, constituting an average of 76% of the U.S landings between 1981 and 2007, however it has accounted for at least 87% of the total U.S. landings since 2002. Southern New England has the second largest fishery accounting for an average of 19% of the U.S. landings between 1981 and 2007. This fishery has experienced dramatic declines in landings and has accounted for 9% or less of the U.S. landings since 2002, and reached time series lows of 6% in 2005 and 2006. Georges Bank constitutes the smallest portion of the U.S. fishery, averaging 5% of the landings from 1981 to 2007. During this time period the relative contribution of the Georges Bank fishery to the total U.S. fishery has remained fairly stable. For this assessment, 2007 landings are preliminary estimates (section 5.1.3).

The total number of fishing permits issued (Table 3.2.1.1) in the U.S. lobster fishery varied around a time series mean of 11,900 from 1981 to 2000. Starting in 2001, the total number of permits steadily declined, reaching the time series low of 10,763 in 2007. This pattern is not homogeneous among states. The states of Connecticut, Maine, and Massachusetts have exhibited declines in the number of licenses issued from highs observed in the early to mid- 1980's. The number of permits issued in Rhode Island and New Hampshire has varied without trend from the beginning of the time series to the late 1990's, experienced notable increases (17% and 8% respectively) from 2000 to 2004, and have declined slightly in recent years. These increases are due to the lack of a limited entry scheme in these jurisdictions. The state of New York had a sharp increase in the number of permits issued from the early 1980's to the mid-1990's, reaching the high of 1,265 permits in 1994. Subsequently, the number of permits issued dropped dramatically from 1995 to 2007 reaching levels last observed in the early 1980's.

Traps are the predominant gear type employed in the U.S. lobster fishery. Between 1981 and 2007 traps accounted for an average of 98% of the total landings. All other gear types (otter trawl, gill net, dredge, SCUBA) accounting for the remaining 2% of the total landings. The standard unit of fishing effort is difficult to define in the American lobster fishery. There is not a linear relationship between the number of traps fished and fishing effort. Many factors affect the catch rates of lobster traps including location, bait, trap design, soak time, temperature, and the presence of other animals (Cobb, 1995). This complicates the relationships between catches or CPUE and abundance or densities, as well as between effort and mortality (Miller, 1989, 1990; Karnofsky and Price, 1989; Addison and Bell, 1997; Addison and Bannister, 1998). A comprehensive description of the factors affecting lobster catchability and trap efficiency is provided in *ASMFC 2000.* The number of trap hauls would be a much better metric of fishing effort, but unfortunately these data are either not currently collected, or not historically available, from most jurisdictions within the U. S. lobster fishery. To characterize fishing effort, the total number of traps fished by state within each stock are presented. Although it is not the best characterization of fishing effort in a trap fishery, it is the only metric that is broadly available. In addition to this we present the number of trap hauls by stock for those jurisdictions in which these data are available (Tables 3.2.1.2). These data are not complete enough to describe trends within stock units. However, we feel it is important to at least include them in tabular form within this assessment to highlight the need to improve fisheries data collection in the U.S. lobster fishery.

The operational characteristics of the U.S. lobster fishery have changed significantly in recent decades. There have been substantial increases in trap numbers, average trap size, and average boat size. The predominant type of trap used in the fishery has changed from the traditional wood lathe traps to wire mesh traps. Advances in radar, sonar, and navigational electronics have increased the efficiency of fishing vessels. Each of these factors affects catch rates and overall yield, and has increased the fishing power of the U.S. lobster fleet. The U.S. lobster landings by state are presented in Table 3.2.1.3. Landings in the state of Maine have steadily increased since the late 1980's, while landings in all other states have remained stable or declined in the last decade. The 1982 – 2003 landings used in the current assessment were updated in response to quality assurance analyses (Table 3.2.1.4). Annual changes were less than 2% of the coastwide landings.

3.2.2 Gulf of Maine

The Gulf of Maine fishery is primarily carried out by fishermen from the states of Maine, Massachusetts, and New Hampshire. This fleet is comprised mainly of small vessels (22 and 42 feet) that make day trips in nearshore waters (less than 12 miles). The Gulf of Maine also has a smaller-scale offshore fishery comprised of larger boats that make multi-day trips.

Commercial lobster landings in the Gulf of Maine were stable between 1981 and 1989 averaging 14,600 metric tons, then increased dramatically from 1990 (19,200 mt) to 2000 (31,727 mt). Since 2000 landings have remained above 30,000 metric tons in 6 out of the last 8 years, and hit a time series high of 37,297 metric tons in 2006 (Table and Figure 3.2.2.1). The increase in landings in the GOM was dominated by catch from the state of Maine, particularly from the mid-coast portion of the state. In Maine landings tripled between 1981 and 2003 and have remained high since this time. The period from 2004 to 2007 accounted for the three highest landings values in the time series. Landings from New Hampshire varied without trend around a mean of 613 metric tons between 1981 and 2003. In 2004 the New Hampshire landings increased dramatically to 968 metric tons and have dropped back down closer to median levels (649 mt) in the last three years. Massachusetts landings increased from 1981 to 1990 and remained high between 1991 and 2000 (averaging 4,979 mt). Starting in 2001 Massachusetts landings declined dramatically reaching a time series low in 2005 (3,227 mt), with six out of the seven lowest landings values in the time series occurring between 2001 and 2007.

The number of traps fished in the Gulf of Maine was fairly stable between 1982 and 1993 averaging approximately 2.3 million traps. From 1993 (2.2 million) to 2002 (3.5 million) the number of traps fished in the GOM increased substantially, and has remained above 3.5 million traps since this time (Table and Figure 3.2.2.2). The number of traps fished within the period from 2002 to 2007 accounting for the six highest levels of traps fished in the time series. The state of Maine accounts for the greatest proportion of the total fishing effort within the GOM stock. Maine accounted for an average of 86% of the total number of traps fished in the GOM between 1982 and 2007. In the Maine fishery, trap numbers varied without trend around an average of 2 million between 1982 and 1993, and then increased substantially reaching a time series high of 3.25 million in 2006. The trend in the Massachusetts portion of the fishery is quite different. Traps increased substantially from a time series low in 1982 (247,000 traps) to a time series high in 1991 (399,000 traps), and remained fairly stable between 1992 and 2002, averaging 382,555 traps annually. Since 2003, traps have declined steadily, reaching 339,000 in 2007. Effort data for the New Hampshire fishery is only available from 1989 to present, during which time traps fished exhibit a slight increasing trend.

3.2.3 Georges Bank

The Georges Bank fishery is primarily carried out by fishermen from the states of Massachusetts and Rhode Island, with a smaller number of participants from Connecticut and New Hampshire. This fleet is comprised of larger vessels (55 to 75 feet) which make multi-day trips in offshore waters (> 12 miles). Georges Bank also has a smaller-scale inshore fishery comprised of smaller boats that make day trips along the outer arm of Cape Cod.

Commercial lobster landings in the GBK stock unit varied around the time series mean of 1,300 metric tons between 1981 and 2002 (Table and Figure 3.2.3.1). From 2003 to 2005 landing increased, reaching a time series high of 2,394 metric tons in 2005, and have remained well above the time series mean through 2007. Catch from the state of Massachusetts comprised the majority of the GBK landings, averaging 66% of the total GBK landings from 1981 to 2007. The proportion of the Georges Bank fishery attributable to Massachusetts has increased over time, whereas the proportion attributable to Rhode Island has decreased. This trend is related to where the respective fisheries in Massachusetts and Rhode Island occur on Georges Bank. The majority of the Massachusetts landings from the Georges Bank stock are harvested on the northern and eastern side of the bank (NMFS Statistical Areas 521, 522, 561, and 562), which have experienced lobster landings increases over the course of the time series. Conversely, the majority of the Rhode Island fishery on Georges Bank occurs on the southern edge of the bank (NMFS Statistical Areas 525 and 526), in which landings have steadily declined over the course of the time series. Prior to 1993, New Hampshire did not have consistent landings in GBK. From 1993 to 2003 NH landings were stable, averaging 113 metric tons. Since 2004, NH landings have increased and have remained more than double the time series mean. Landings from all other states comprised less than 5% of the GBK landings throughout the time series.

The number of traps fished on Georges Bank is not well characterized, due to a lack of mandatory reporting, and/or a lack of the appropriate resolution in the reporting system. Massachusetts is the only state that has a time series of effort data for this stock. As such, Massachusetts data are presented here as an index of relative effort for the Georges Bank stock. The number of traps fished on Georges Bank increased steadily from early 1980's to the mid-1990's, reaching a time series high in 1994 (47,800 traps, Table and Figure 3.2.3.2). From 1994 to 2007 the number of traps has varied without trend around a mean of 43,000.

3.2.4 Southern New England

The Southern New England fishery is carried out by fishermen from the states of Connecticut, Massachusetts, New York, and Rhode Island, with smaller contributions from the states of New Jersey, Delaware, and Maryland. This fleet is comprised mainly of small vessels (22 and 42 feet) that make day trips in nearshore waters (less than 12 miles). Southern New England also has a considerable offshore fishery comprised of larger boats (55' to 75') that make multi-day trips to the canyons along the continental shelf.

Commercial landings in the Southern New England stock increased sharply from the early 1980's to the late 1990's, reaching a time series high of 9,935 metric tons in 1997. Landings remained near time series highs until 1999, then declined dramatically back to levels observed in the early 1980's (Table and Figure 3.2.4.1). Four out of the five lowest levels of lobster landings in the SNE stock have occurred since 2003. The majority of the catch in SNE is landed by Rhode Island (1981 to 2007 mean = 38 %), followed by New York (22%), Connecticut (15%), Massachusetts (15%), and New Jersey/Delaware/Maryland/Virginia (10%) in descending order. Landings trends among states within the SNE stock were generally similar to the overall trend. One notable exception is New York, where the increase in the late 1990's and decline in the early 2000's are much more dramatic.

The estimated total number of traps reported fished for the Southern New England stock unit only includes data from Connecticut, Massachusetts, and New York. Rhode Island data are not included in the totals because these data were not consistently collected throughout the time series and data are not available for states south of New York. As such the magnitude of the traps fished given for SNE is likely to be substantially underestimated because RI has historically had the largest fishery in this stock. Despite this limitation, we expect that the total number of traps fished for SNE based only on data from Connecticut, Massachusetts and New York accurately depict the trends in fishing effort in this stock unit. This expectation is based on the very close agreement in trends in traps fished among CT, MA, and NY, as well as the close agreement in landings trends among all jurisdictions within the SNE stock unit.

Between 1981 and 1998 the number of traps fished in SNE increased six fold and reached a series high of 600,000 traps in 1998. Between 1999 and 2007 the number of traps fished declined by 63%, though current numbers of traps are twice the numbers reported in the early 1980's (Table and Figure 3.2.4.2). This large decline in fishing effort is most likely the result of a combination of regulatory changes to reduce effort, declining stock size and substantial increases in operating cost in the fishery associated with fuel and bait.

4.0 Habitat

4.1 Temperature

Water temperatures exert significant influence on reproductive and developmental processes of lobster. Temperatures must reach 8-10 °C during winter in order to maintain a balance between the synchronization of the molt and ovarian development cycles in female lobster (Aiken and Waddy 1986). In northern waters, warmer winter temperatures favor molting but cause oocyte resorption (Aiken and Waddy 1986). Photoperiod has been implicated as a factor governing spawning (Nelson et al. 1983).

Temperature has a strong effect on embryonic development with the onset of hatching varying with year, location and the temperature history of females (Aiken and Waddy 1986). Since temperature can affect the rate at which the embryo assimilates lipids, delayed hatching may result in depletion of lipid reserves, which are important to survival during the pelagic larval stages. The duration of the planktonic phase is dependent upon seawater temperature. Huntsman (1923, 1924) found that larvae hatched in water less than 15°C developed much more slowly than those hatched in warmer water. Time from hatching to stage IV is approximately 10 days at 22-24°C and nearly two months at 10°C, while at 5°C larvae generally die without reaching stage IV (Templeman 1936).

Temperature also has a significant impact on benthic juvenile and adult lobster growth, survival and reproduction. Aiken and Waddy (1986) reported that juvenile and adult lobster are found seasonally in waters ranging from 0°C to 25°C. Tolerance of high temperatures depends on acclimation, but tolerance to even moderately high temperature declines as optimal dissolved oxygen and salinity levels decrease. Several laboratory studies have demonstrated the strong physiological and behavioral relationship with temperature. In the laboratory, the strength of a lobster's heartbeat (contraction amplitude) decreases by more than 60% as they are warmed from 2 to 22°C, but heart rate increased (Worden et al. 2006). This study also showed that cardiac output, as a combination of heart rate and stroke volume, is maximal at 10°C and significantly decreases above 20°C. In another study lobster held at 21°C and 23°C had significantly higher respiration rates than those held at 18°C and 19.5°C (Powers et al. 2004). These high respiration rates were considered stressful and the authors concluded that a distinct thermal threshold exists for southern lobster at 20.5°C. Even normal respiration rates can become problematic because high water temperatures often combine with hypoxia, and sometimes the release of sulfides and ammonia into the water column from enriched sediments (Robohm and Draxler. 2003). This combination of events can often be lethal for lobster and other benthic invertebrates. Behaviorally, lobster acclimated to 15.5°C demonstrated a preference for temperatures between 15-18°C and an avoidance of temperatures above 19°C (Crossin et al. 1998).

4.2 Currents

In contrast to the gradual development of fish, crustaceans pass through a series of distinct larval stages that are punctuated by molts. It is within these larval stages where principal forcing agents such as wind stress, tides, differences in water mass density and directed swimming can impact the distribution and abundance of marine crustaceans and our interpretations of stock structure (Epifanio and Garvine 2001).

American lobster eggs are carried on the abdomen of the female for 9 to 12 months before hatching. Prelarvae are released by the female over the course of several days and molt into positively buoyant 1st stage zoeal larvae. The 1st, 2nd and 3rd stage zoeal larvae remain planktonic for approximately 15-30 days and become distributed throughout the water column (Harding et al. 1987). In their 4th stage, they metamorphose to postlarvae that actively swim at the surface for 10 to 30 days (Cobb et al. 1989) before making the transition from pelagic to benthic habitats. At any of these stages lobster can be transported considerable distances (e.g., Katz et al. 1994).

The Gulf of Maine is a semienclosed marginal sea with several deep basins, strong tidal currents and a generally cyclonic circulation. Scotian Shelf water enters along the south coast of Nova Scotia and exits primarily along the northern edge of Georges Bank and secondarily through the Great South Channel (Brooks 1985). Larval transport is one mechanism that links inshore (coastal) and offshore (basin) lobster. Fogarty (1998) calculated that a modest amount of offshore larval supply could add significantly to resiliency of populations in inshore areas. With hatching occurring over a period of two months, beginning generally in late June in southern areas and a month later in northern areas, conditions experienced by developing larvae can be very different. Favorable conditions for larvae can greatly increase development rate and when coupled with the typical physical forcing factors observed within the Gulf of Maine, as described above, create a delivery mechanism of competent larvae to nearshore nursery grounds (Incze and Naimie 2000).

As larvae develop in the summer on Georges Bank, a strong cyclonic gyre tightens and increases residence time to 50 days inside the 100 m isobath (GLOBEC 1997). Wind and eddy events may periodically transport larvae off the Bank, but they are unlikely to strongly impact the supply of larvae to coastal Nova Scotia and other northern areas of the Gulf of Maine (Harding et al. 2005).

The Southern New England stock area is characterized by weaker tidal currents than the Gulf of Maine and Georges Bank. Consequently, drift was found to be highly wind dependent, with tidal currents only influencing short term movements. Fogarty (1983) observed peak larval densities following periods of inshore winds in the days preceding sampling in Block Island Sound and identified offshore areas and Long Island Sound as larval sources. Lund and Stewart (1970) suggest that relatively high concentrations of larvae in western Long Island Sound are a result of surface currents creating a larval retention area. This notion of oceanographic forcing is confirmed in a review by Epifanio and Garvine (2001) who suggest that larval transport is primarily influenced by inshore wind stress and water density differences along the Atlantic continental shelf.

4.3 Salinity

The impermeable membrane of lobster eggs may provide some measure of protection for the embryo against low salinity because embryos require a longer adaptation time to low salinity than hatchlings or prelarvae (Charmantier and Aiken 1987). In contrast, juveniles and adults can tolerate a broad range of salinity, from 15-32 ppt (Harding 1992). Larval lobster are sensitive to salinity below 20 ppt and swim to greater depths to avoid lower salinity surface waters. Larval stages I-III are more adaptable to low salinity than stage IV (Charmantier et al. 1984) and less resistant to elevated salinity than postlarvae and juveniles (Charmantier et al. 1985). No stage III or IV larvae survived salinity below 12.5 ppt. No larval molting occurred beyond a salinity of approximately 40 ppt. Changes in salinity present a greater problem for pelagic larvae than for benthic juveniles and adults because they are more directly exposed to rainfall (Aiken and Waddy 1986), although excessive runoff can lower bottom salinity and cause mortality. Lobster prefer higher salinity (20-25 ppt) over lower (10-15 ppt) values (Jury et al. 1994). In addition, males tolerate lower estuarine salinity better than females, a fact that explains why males are more abundant in trawl surveys in the inner reaches of Narragansett Bay than in the outer bay (Castro, 1998a.).

4.4 Dissolved Oxygen

Adult lobster demonstrate a behavioral avoidance of dissolved oxygen (DO) levels below 2 ppm (Howell and Simpson 1994). As juvenile and adult lobster prepare to molt they are more susceptible to low DO because oxygen consumption peaks at molting (Penkoff and Thurberg 1982). Oxygen consumption also increases with stress, feeding, increased activity and water temperature (McLeese 1956, see section 4.1). Miller et al. (1992) found that larval lobster appear twice as sensitive as juveniles and adults to reduced DO. However, since larvae are planktonic, spending a good deal of time in the upper water column, encountering low DO would be a rare event.

4.5 Substrate

During settlement, 4th stage post-larvae exhibit strong habitat selection behavior and seek small shelter-providing substrates (Hudon 1987; Wahle and Steneck 1991, 1992; Incze et al. 1998; Palma et al. 1999). Highest abundance of newly settled lobster has been reported in cobble beds (Wahle and Steneck 1991; Cobb and Wahle 1994; Palma et al. 1999), while lower densities have been found reported on other substrates including in marsh grass root mats in southern New England (Able et al.1988). Young-of-year lobster are rare or absent from sediment substrates and eel grass habitats although early benthic phase lobster (sensu Steneck 1989; Wahle and Steneck 1991 for lobster < 40 mm CL) are not.

Early benthic phase lobster are cryptic and quite restricted in habitat use (Wahle and Steneck 1991; Lawton and Lavalli 1995). They usually do not emerge from their shelters until reaching about 25 mm CL (Wahle and Steneck 1992; Cobb and Wahle 1994). Larger, but still immature, adolescent phase lobster are found on a variety of bottom types, usually characterized by an abundance of potential shelters. Inshore, they are found in greatest abundance in boulder areas

(Cooper and Uzmann 1980) but they also seek shelter under large algae such as kelp (Bologna and Steneck 1993). Adolescent phase lobster also live on relatively featureless substrate where juvenile population densities are generally low (Palma et al.1999). Juvenile densities are high in shallow water, (0-30 ft) on sand, and mud substrate in inshore Massachusetts waters (Estrella, personal communication).

5.0 Data Sources

5.1 Fishery Dependent

5.1.1 Commercial Catch

5.1.1.1 Data Collection Methods

Maine

Lobster landings information from dealers is compiled in the National Marine Fisheries Service (NMFS) weigh out and canvass database by port and month. Landings reporting was voluntary by dealers prior to 2004; when monthly landings reports became mandatory and a requirement for license renewal. A lookup table was supplied by Maine Department of Marine Resources (DMR) to ASMFC linking port landed (designated by NMFS port codes) with likely statistical area from which lobster were harvested. For all years it was assumed that port codes sufficiently characterized the spatial distribution of landings in Maine.

During the 1990s, the Maine lobster fishery was in a period of rapid growth. New dealers were buying significant quantities of lobster in locations where previously minor fisheries existed, seasonal dealers began buying lobster out of trucks/vans and lobster smacks, and Canadian processing plants began buying excess lobster from Maine. Given the magnitude of the changes in the fishery, it is very likely that significant landings were missed through the voluntary landings reporting program during the period of 1997 through 2003. Based on the port-sampling index, reported landings were increased by 32%, to create an alternate landings stream for the State of Maine from 1997 to 2003 was created for testing and review during this assessment (Appendix 1 Table 2).

New Hampshire

New Hampshire (NH) lobster harvesters have been reporting annual inshore lobster landings data since 1969 to the New Hampshire Fish and Game Department (NHFG). Between 1969 and 1985 mandatory annual reports from all lobster harvesters were compiled to produce annual lobster harvest totals. Between 1986 and 2005, a random selection (RSL) of a percentage of licensed lobster harvesters and all new entrants into the lobster fishery were required to report harvest and effort data. The reported data were expanded to reflect the total estimated inshore landings of lobster. The RSL reports were submitted monthly and collected the following trip-level information: month and day fished, number of gear fished (both monthly and daily totals), area fished, average set over days/pot, weight of harvest, gear size, did fish or did not fish, and incidental catch. The reports submitted by new entrants were submitted annually and represented monthly-summarized catch and effort information from New Hampshire inshore waters. Beginning in 2006, all licensed lobster harvesters are required to report harvest and effort data.

Harvesters are required to report monthly, trip-level data collecting all ACCSP standard data elements if they landed 1,000 pounds or more the previous year, or annual, monthly-summarized data if they landed less than 1,000 pounds the previous year. Any harvester may elect to report trip-level data on a monthly basis using the NHFG developed Electronic Harvester Reporting Program (EHTR).

NMFS has also collected lobster harvest and landings data from NH's lobster industry. NH seafood dealers reported through volunteer annual seafood dealer reports prior to 2005 and mandatory seafood dealer reports since 2005. NH instituted mandatory lobster dealer reporting in 2005 in cooperation with NMFS to account for all NH lobster dealer landings and collect all data required under ACCSP standardized data submission standards. NH lobster dealers report transaction-level data on a monthly basis through use of paper logbooks and flat files to NHFG for entry into the EDR (Electronic Dealer Reporting program), or directly to EDR.

NMFS has mandatory reporting of harvest data from the majority of federally permitted vessels that land in NH. Some of these federally permitted lobster harvesters may also fish in state waters. Because of the differences in data collection, prior to 2006, NH inshore lobster landings data between NMFS and NHFG do not agree. The NMFS data are generally inconsistent in representation of inshore landings since 1981, as NMFS only utilized those dealers that volunteered to report lobster landing transactions. Some years appear to have offshore landings data mixed with inshore landings thereby inflating inshore landings. In other years, the inshore data are dramatically lower than NHFG estimates, possibly due to the decrease in volunteer federal reporting by NH dealers of lobster landings data.

Total monthly landings from the NMFS Weighout and Canvass database were used to calculate landings data for this recent stock assessment for all years except 2004. Due to extreme data gaps identified with NMFS seafood dealer landings data for 2004, NHFG audited the combined 2004 NMFS dealer and Vessel Trip reports (VTR) with NHFG inshore lobster reports and eliminated duplications and resolved discrepancies among the three datasets. The final numbers reported for 2004 reflect a more complete accounting of the total landings of lobster from all three datasets and may still be an underestimate of the total landings as a result of estimated totals from NH's inshore lobster harvester RSL reporting.

Massachusetts

Commercial lobstermen (coastal, offshore, and seasonal or student) receive a detailed annual catch report form with their license renewal application. This report requests the following information on a monthly basis: method of fishing; number and type of gear used; effort data (set-over days, number of trips per month, etc.); pounds of lobster caught; areas fished; principal ports of landing; and information relative to the vessels and traps used in the fishery. All Massachusetts lobster statistical reporting areas align with NMFS statistical reporting areas in sum for inshore areas, and in total for offshore areas.

Rhode Island

Commercial lobster fishery landings data prior to April 1994 were collated directly from the NMFS weighout and canvass database. In 1999, Rhode Island initiated a mandatory commercial lobster catch/effort logbook reporting program as part of the Atlantic Coastal Cooperative

Statistics Program (ACCSP). This data is used in conjunction with the NMFS Vessel Trip Report (VTR) landings data system to calculate total Rhode Island lobster landings by statistical area. Beginning in 2003, RI logbook data and NMFS VTR data were used in place of NMFS dealer reports for the assessment. Based on an analysis of logbook versus NMFS dealer data (M. Gibson, RIDFW, personal communication), landings in some earlier years (1981-1982 and 1995-1998) were adjusted upward to compensate for likely underreporting of landings in those years. For the years 1981-1982, the sum of 1982-1989 NMFS weighout and canvas numbers were divided by the sum of 1982-1989 NMFS weighout numbers and that ratio (~1.041) was then multiplied by 1981-1982 canvas numbers to obtain final adjusted landings for each year. For the years 1995-1998, the sum of 1999-2003 NMFS weighout and canvas numbers were divided by the sum of 1999-2003 NMFS weighout numbers and that ratio (~1.118) was multiplied by 1995-1998 canvas numbers to obtain final adjusted landings for each year. For the years 2004 to the present, total commercial lobster landings are compiled from combined RI logbook and NMFS VTR data.

Connecticut

Landings are recorded in the NMFS weighout and general canvass database as landings at state ports. Connecticut also records landings by licensed commercial fishermen in any port (inside or outside CT) by means of a mandatory logbook system that provides catch and effort information from 1979 to the present. This mandatory monthly logbook system provides a detailed daily catch by species, area, and gear as well as port landed, traps hauled, set over days, and hours trawled (for draggers). The logbook provides a means to look at fundamental changes in the operating characteristics of the lobster fishery within Long Island Sound. Since 1995, the program has required fishermen to report information on the sale and disposition of the catch, including the state or federal permit number of the dealer to whom they sold their catch. Seafood dealers are also required to report all of their individual purchases from commercial fishermen using either the NOAA form *Purchases from Fishing Vessels,* a C*onnecticut Seafood Dealer Report, Abbreviated Form for Lobster Transactions Only*, or through the ACCSP's Standard Atlantic Fisheries Information System. A quality assurance program has been established to verify the accuracy of reported statistics through law enforcement coverage and electronic crosschecking of fisherman catch reports, law enforcement boarding reports, and seafood dealer reports.

New York

New York commercial lobster landings from 1981 through 2003 were obtained from the NMFS weigh out and canvass database. The NMFS weigh out and canvass data from 1998 through 2006 was compared to NY Recall Survey data for the same years. The difference in reported landings ranged from -4% (NY recall higher than NMFS) to 33% (NMFS data higher than NY recall). The three highest percentage differences occurred during 2004 through 2006. Preliminary comparison of Federal dealer data and NY recall survey information from this time period indicated there was some double counting of landings. Since the difference between NMFS and NY landings were not large before 2004, lobster landings data provided by NMFS for the period from 1981 through 2003 were utilized. Due to the potential magnitude of double counting from 2004 through 2007, NY conducted an analysis to reconcile the lobster landings data. NY and NMFS staff collaborated on the development of the reconciliation process, and NY staff conducted the analysis. Below is a description of the reconciliation process.

NY reconciled the lobster landings data by comparing landings information submitted in Federal and State dealer reports, Federal Vessel Trip reports (VTR), and NY annual recall surveys. The first step was to link the Federal and State data. Federal licenses are issued to vessels, while NY licenses individuals. Vessel identification numbers (documentation or State registration numbers) were linked to individual fishers utilizing NY and NMFS licensing information. The analysis was conducted on an individual/vessel level.

Dealer reported landings were considered most reliable, since the landings are weighed and not estimated. Dealer reports from CODES and SAFIS databases were compared for each individual/vessel. For 2004 through 2006 the SAFIS database contained a subset of information contained in CODES. Therefore, dealer reported landings from CODES were utilized from 2004 through 2006. The CODES database was not utilized during 2007; all dealer data (Federal and State) were entered into SAFIS. The 2007 data utilized for the reconciliation was an update of the SAFIS landings provided by NMFS (V. Vecchio, NMFS, personal communication).

The next step was to compare the dealer reported landings with landings reported by Federal VTR's. NMFS staff (V. Vecchio, NMFS, personal communication), recommended utilizing a 5% cutoff for use of VTR data in place of the dealer data. Therefore if the VTR reported landings for an individual/vessel was 5% greater than what was reported in dealer reports, the VTR landings were used instead of the dealer landings. In addition, if the dealer reported landings were used but were missing information on area fished, the proportion of landings fished by area reported in VTR's (if available) was applied to the dealer landings to estimate the landings by area.

The final comparison was with the NY Recall Survey. This was considered the most unreliable information. NY fishers report on their previous years landings when they renew their license. Due to the assumed unreliability of the survey a 25% cutoff was utilized. Therefore, if an individual/vessel's reported landings were 25% higher in the NY recall survey compared to the dealer/VTR landings, the additional NY recall landings by area was included (the landings were added to the dealer/VTR landings). In addition, if the dealer/VTR landings were missing area fished information, the proportion of landings by area reported in NY recall survey (if available) was applied to the dealer/VTR landings to estimate the landings by area.

New Jersey South

New Jersey, Delaware, Maryland, Virginia, and North Carolina collect no landings data for American lobster. Total monthly landings from the NMFS weighout and canvass database were used to calculate landings data for this recent stock assessment.

5.1.1.2 Commercial Discards/Bycatch

Little data are currently available on commercial discards and bycatch of lobster in the lobster fishery. Sea sample data indicate substantial regulatory and market driven discard of sub-legal, oversized, v-notched, and ovigerous. The regulatory discard is accommodated in modeling as a component of gear selectivity. Studies describing discard mortality in the trap fishery and/or bycatch mortality in the trawl fishery are limited but consistent in their findings that most mortality factors are relatively low. A two-year study of both trap and trawl catches in Long

Island Sound showed that hardshell (intermolt) lobsters suffered little damage by commercial trawling, with the incidence of immediate mortality by month never exceeding 0.5% in the trap fishery or 2.2% in the trawl fishery (Smith and Howell 1987). Additionally, this study examined delayed mortality (up to 14 days) in the laboratory and found it occurred almost exclusively in hardshell lobster sustaining major damage to the carapace or tail, or in newshell lobster. Ganz (1980) also found low immediate mortality to trawl-caught American lobster in Narragansett Bay, RI, and low damage rates during intermolt periods. Both of these studies found that damage rates were higher immediately following molting, but that newly molted animals made up a very small percentage of the catch because of their reclusive behavior. Two other studies of scallop (Jamieson and Campbell 1985) and rake (Scarratt 1972) fisheries found that although the gear could damage American lobster, the lobster emigrated from the area during the harvest season and so the gear had no significant impact on the lobster population present on the grounds at other times of the year. The model assumes a 0% discard mortality rate.

5.1.1.3 Gapfilling and Expansions

To account for landings "gaps" (landings reported with unknown statistical area and/or month), a number of adjustments and expansions of recent landings data were conducted. Decisions listed below were used to fill areal and temporal gaps in the landings and thus to ensure that all landings data used in the assessment had associated statistical area, month, and year information. Landings prior to 2004 were similarly gap-filled (see Appendix 1 ASMFC 2006). Each specific change to the original dataset is documented and explained in the ASMFC lobster database metadata.

Landings gapfilling rules:

- Landings with unassigned statistical areas were allocated based on the proportion of landings in all statistical areas averaged over the surrounding 5-year period (two years before the year being filled and two years after). In later years, averaged proportions were taken from 2002-2006.
- Landings designated statistical area 510 were allocated across other 51X areas; landings designated statistical area 500 were allocated across all 5XX areas; landings designated statistical area 000 were allocated across all areas appropriate for each state.
- Landings with unassigned months were allocated based on a monthly proportion of the ten-year average landings in that statistical area. (1990 to 1999 for data prior to 2004 and 1999 – 2003 for 2004 to 2007 landings).

Exceptions/additions:

- Maine: updates and corrections to the port lookup table were made.
- New Jersey and Maine: Landings in unassigned months in recent years were allocated based on monthly proportions within the same year due to concerns about long-term changes in seasonality of catches.
- Connecticut and Rhode Island: 2004-2006 landings data contained no landings gaps
- New York –Landings from 1981 through 2003 with un-assigned months were allocated based on a monthly proportion of the ten year average (1990 – 1999) utilizing either monthly proportions from CT landings data for statistical area 611 (CT had no unknown months for 611 during that time period) or NY landings data for Atlantic Ocean statistical areas combined. Landings from 2004 through 2006 with un-assigned months were allocated based on a monthly

proportion of the five year average (1999 – 2003) utilizing NY landings data from either statistical area 611 or Atlantic Ocean statistical areas combined. Monthly proportions of landings in Ocean statistical areas 500's versus 600's were examined, there was little difference, and therefore they were combined.

5.1.1.4 Size Structure of Commercial Catches

Sea sampling of commercial catches showed a consistent size range for legal size in the Gulf of Maine from 1981 to 2007 (Figure 5.1.1.4.1 and 5.1.1.4.2). Median size varied only two millimeters (mm) (87mm to 89mm CL) for females over the time series, and three millimeters (87mm to 90 mm CL) for males. The 75th percentile varied three and four millimeters respectively for females and males. Ninety-nine percent of the landings encompass approximately 30% of the size range, with an extreme left skew where the largest 1% of the catch encompasses the remaining 70% of the size range. The median size and size range of the legal catch of males and females sampled on Georges Bank also varied without trend from 1981-2003. The median and size range increased 15 – 20% from 2004 to 2007 for females, and for males the size range increased by 16% while the median only increased by 4% (Figures 5.1.1.4.3 and 5.1.1.4.4). This increase encompassed a time period where minimum size limits on Georges Bank increased from 85mm to 88mm (ASMFC 2006). The median size of the legal catch sampled in Southern New England ranged from 85mm to 88mm from 1981 to 2002 (Figure 5.1.1.4.5 and 5.1.1.4.6). Median size increased to 89mm for females and 91mm for males from 2003 to 2007. The 99th percentile for both females and males declined in size from 1982 to 1993, remained stable at low size from 1994 to 2001, and then increased from 2002 to 2007. Minimum size limits in Southern New England increased from 83mm to 86mm from 2002 to 2007, except LCMA 6 (Table 1.2).

5.1.1.5 Size Structure of the Offshore Commercial Catch

The Atlantic Offshore Lobstermen's Association (AOLA) initiated a volunteer sea-sampling program in September 2001 involving twenty fishing vessels. Participants collected information on all lobster caught in a standard offshore lobster trawl of approximately 40 traps, as it is fished during normal fishing practices (hauled approximately once per week, 10-11 months of the year). Summarized catch data (legal/sublegal counts; counts of ovigerous, v-notched, or shell diseased lobster) were recorded for three quarters of the traps. In the remaining one quarter of traps specific biological information was collected for each lobster including: size (using a millimeter gauge), sex, ovigerous status and the stage of eggs, and shell disease status and the stage of shell disease. These data, as well as location (specific latitude and longitude as well as federal statistical area), depth, trawl size, trap vent size, and legal gauge size were reported. Data were collected all years from statistical areas in the Gulf of Maine and Georges Bank, but only for 2001-2002 in statistical areas in Southern New England.

Enough data were collected from Georges Bank to examine length frequencies from northern and southern areas separately (Figure 5.1.1.5.1). Median lengths were highest in catches from the northern areas of the Bank followed by offshore areas of the Gulf of Maine. Although median lengths for males exceeded median lengths for females in both of these areas, the largest animals in the northern GBK catches were female. The smallest median lengths were recorded in the southern areas of the Bank, which were similar to lengths recorded in the Southern New England areas. Sex ratios of legally harvestable animals (percent non-ovigerous, non-notched females) were well balanced for catches in Southern New England and Georges Bank, but heavily weighted toward females for catches in the Gulf of Maine.

5.1.2 Biological Samples

5.1.2.1 Data Collection Methods: Port and Sea Biological Samples

NMFS, NEFSC

NEFSC Observer Program (Sea Sampling) began (for lobster) in 1991. Data collected are stored in multiple tables, the primary two are: (1) a species catch record and (2) the characteristics of hauls. Data are stored in a relational database and therefore all information can be linked by individual trip. Biological data collected, relevant to assessment work include: year and month landed, unique 6-character by month (for link), species, total number caught in haul, indicator of whether number recorded was actual or estimated, percentage of animals that show signs of shell disease, carapace length in whole millimeters, lobster kept, discarded and reason for discard, eggs visible; v-notch (if yes, old or new), shell condition and number of claws on lobster sampled. Haul data collected include: year and month landed, unique 6-character by month (for link), ordinal number of haul within the trip; gear code, depth, condition of gear, species named by captain as targeted for haul or trip; year/month/day/time/date set and haul began and ended, surface temperature when haul ended; amount of time that the gear for haul is in the water, location of set and haul in latitude/longitude and GIS, inshore area codes and statistical area code.

Data for are available from 1983 from the port sampling program. The current target number of trips (using lobster pot gear) is around 50, with about 40% covering statistical area 515; 35% on GBK; a few in SNE and the remainder in GOM and GBK combined. The current target number of trips (using lobster pot gear) is around 50, with about 40% covering statistical area 515; 35% on GBK; a few in SNE and the remainder in GOM and GBK combined. Data collected, relevant to assessment work include: year, month, day, port, state, gear, nespp4 (market category), statistical area, inshore area codes, landed weight, sex, weight of sample, number sampled, length, number at length.

Maine

Fully implemented in 1967, DMR has conducted sampling during ten randomly selected days each month from April through December. Port samplers survey lobster dealers along the entire coast who buy from at least five commercial lobstermen. This survey is designed to produce unbiased expanded estimates of catch, effort, sex, and size distribution of the landed catch for the entire fishery on a monthly and annual basis (see Appendix 1). Recorded data includes number of traps hauled during each trip, number of days traps were immersed, total weight of catch, number of lobster caught, and hydrographic information. Ten lobster from each boat are randomly selected to provide individual length and weight data, as well as sex, claw, and shell condition.

A sea sampling program was started in 1985 during the months of May through November aboard commercial lobster vessels using observers to record data. Prior to 1998, sea sampling was limited to only three locations with repeated trips made aboard the same vessels. This program was expanded in 1998 to sample each of Maine's seven lobster management zones three times a month during the months of May through November. A limited winter sampling program has been developed in recent years that averages one sampling trip per month per statistical area December through April. Biological data collected include carapace length (mm), cull status, sex, egg development stage, second abdominal width (discontinued in 1998), v-notch/mutilation condition, presence and condition of eggs, molt condition and finfish by-catch (species and length). In 2003, the incidence of shell disease and dead lobster in traps were incorporated into the sampling protocol. When generating the Catch At Length Matrix for Maine's landings, port and sea sampling lengths have been combined by statistical area and month as the legal size distribution has been shown to be comparable between the two programs (Scheirer et al. 2004).

New Hampshire

NHFG conducts a monthly sea sampling program from May through November aboard commercial fishing vessels in the lower Piscataqua River, state coastal waters, and around the Isles of Shoals (statistical area 513). Data collected since 1991 include catch per unit effort (CPUE), bait and trap type, carapace length, sex, molt stage, cull status, female second abdominal width, v-notch condition, and the presence of eggs.

A port sampling program was initiated in 2005 to collect both CPUE and biological data on harvest landed in New Hampshire. A total of six samples are taken each month from May through November; four from state waters and two from federal waters (EEZ). During each visit, 100 lobster are sampled and an interview with the captain is conducted. Biological data collected include carapace length (mm), sex, molt stage and cull status. The Captain’s interview consists of a variety of questions including: number of trawls hauled, traps per trawl, number of set days, percent of traps that were single parlor, location of area fished and average trap depth.

In past assessments, sea sampling data was used to estimate size distribution of landings by area. The current assessment utilizes lobster data from lobster carapace lengths that have been combined by statistical area and month in years where port sample data was available.

Massachusetts

The Division of Marine Fisheries has conducted a commercial lobster trap sea sampling program since 1981 to collect both biological and CPUE data. Six fixed regions that include all three stock areas are sampled at least once per month from May-November by observers aboard commercial boats. Recorded data includes carapace length (mm), sex, shell hardness, culls and/or other shell damage, external gross pathology, mortality, presence of extruded ova on females, trap locations (latitude and longitude), and water depth (from chart plots) for legal and sub-legal lobster.

The Massachusetts Division of Marine Fisheries has conducted a port-sampling program since 2006. This program is specifically structured to obtain data from offshore lobster fisheries conducted in the Gulf of Maine and on Georges Bank. The sampling strategy is designed to represent a broad geographic range targeting catch from statistical areas which comprise the majority of offshore landings within each stock unit. Statistical area 515 is sampled for the offshore Gulf of Maine, and statistical area 562 is sampled for Georges Bank. One trip per month is conducted in each area. A target number of 600 lobster are sampled during each trip. Biological characteristics including, carapace length (mm), sex, shell hardness, cull status and/or other shell damage, and external gross pathology, are recorded.

In past assessments, sea sampling was used to estimate size distribution of landings by area; in this assessment, port and sea sampling lengths have been combined by statistical area and month in years for which port samples were available.

Rhode Island

The RI Department of Environmental Management has conducted an inshore and offshore trap sea sampling program since 1990. Sampling areas include Narragansett Bay, Rhode Island Sound, mid-continental shelf areas (30-60 fathoms; discontinued after March 2003), and canyon areas (70-200 fathoms). Collected data include catch (weight and number), effort (number of trap-hauls, set-over days), trap type, bait type, bottom type, depth, trap location (LORAN), surface and bottom water temperature, carapace length, sex, presence and developmental stage of extruded eggs, relative fullness of egg mass, shell hardness (molt status), cull status, shell damage/disease, v-notch status, and mortality. Inshore sea sampling is conducted each month (2 sea sampling trips per month) and offshore sea sampling is conducted quarterly (February, May, August, and November).

An offshore port sampling program was initiated in January 2006. The primary objective of the Offshore Port Sampling Program is to collect lobster length frequency and other biological data (i.e. sexual maturity, shell disease frequency and severity,) from offshore NMFS statistical areas (Lobster Conservation Management Area 3) where lobster landings are emanating, but do not have any sampling data to properly characterize the length frequency distribution of the landings from those areas. Accurate area-specific length frequency data is vital for lobster stock assessment purposes in order to provide significantly better quality data used for stock status determinations. Currently, port samples from NMFS Statistical Areas 525, 526, 537 and 616 are collected monthly.

Connecticut

The Connecticut Department of Environmental Protection Marine Fisheries Division has conducted sea sampling trips since 1982 with commercial trap fishermen within Long Island Sound. From 1982-1999, an average of 15 sea sampling trips were taken each year (range 6-28 trips per year). Following the die-off in 1999, expanded sampling effort increased the annual average to 41 trips for 2000-2007 (range 19-77 trips per year). Biological information is recorded for all lobster of all sizes in as many trap hauls as possible. These data include: carapace length (to the nearest mm; 0.1mm for the mm interval encompassing the legal minimum), sex, shell hardness, relative fullness of egg mass, developmental stage of eggs, cull status, and any signs of shell damage or disease. From 1992-1998, pleopods were taken from a large number of females for cement gland staging to determine length at maturity.

New York

NY State Department of Environmental Conservation sea sampling data are collected on cooperating commercial vessels in Long Island Sound (area 611) and the Atlantic Ocean side of Long Island (areas 612 and 613). Data collected include catch, size, sex, egg status, shell disease, soak time, and water quality. Additional analysis of the fishery has been conducted using information supplied on lobster permit applications, such as catch, pots fished, area fished, and number of participants. Fishing effort (number of traps used) can be calculated from this information. Sampling in areas 612 and 613 has always been sporadic and sampling in area 611 was very poor during 1995-1998, and 2003.

A port sampling program began in 2005. The main objective of the program is to enhance the collection of biological data from lobster harvested from LMAs 3, 4 and 5. A communication network was developed with cooperating dealers and fishermen who fish these areas. This network is contacted to identify days and times of vessel landings to provide sampling opportunities. Utilizing this network of contacts allows for the sampling of a high percentage of lobster fishing trips landed in NY from the appropriate LMAs. A random sample of at least 100 lobster is collected from the catch before it is culled. Sampling protocol adheres to the standards and procedures established in NMFS Fishery Statistics Office Biological Sampling Manual.

In past assessments, sea sampling was used to estimate size distribution of landings by area; in this assessment, port and sea sampling lengths have been combined by statistical area and month in years for which port samples were available.

5.1.2.2 Data Resolution and Sampling Intensity

Fishery dependent sampling, via port and sea-sampling programs, are used to characterize the size distribution of commercial landings. Without exception the sampling intensities for each of these programs is set by resource feasibility and logistics, not by statistically derived sampling targets. In general inshore lobster landings from US territorial waters have been fairly well characterized since the early 1980's because of standardized fishery dependent sampling programs conducted by the state agencies of Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine. However, offshore lobster landings have historically been poorly characterized due to a lack of sampling.

One method to examine the sampling intensity of areas within the U.S. lobster fishery is to classify each area into one of three categories based on the quartile ranking of its relative sampling intensity (# of lobster sampled/ landings). The categories of intensity are: low = less than the 25^{th} percentile; moderate = between the 25^{th} and 75^{th} percentile; high = greater than the 75^{th} percentile (Tables 5.1.1.2.1-5.1.1.2.3 and Figures 5.1.2.2.1 and 5.1.2.2.2).

The historical difference in data resolution between inshore and offshore landings is evident when the relative sampling intensity from 1999 to 2003 is examined in each NMFS statistical area (Figure 5.1.2.2.1). In recent years (2006 – 2008) a structured port sampling program targeting offshore areas was initiated by the states of New Hampshire, Massachusetts, Rhode Island, and New York with funding from ASMFC. This program greatly enhanced the sampling intensity in offshore areas, thereby improving data resolution in the offshore portions of all three stock units (Figure 5.1.2.2.2). On a relative scale, for the period of 2003 to 2007, the Gulf of Maine was the best characterized, followed by Georges Bank and Southern New England respectively.

Sampling area intensity maps need to be viewed cautiously because of the nature of quartile designations. With the addition of new data, scales for quartile designations change. As such it is possible for areas in which the absolute sampling intensity did not change to have a change in its relative sampling intensity designation. This problem is evident in a comparison of Figures 1999 to 2003 and 2003 – 2007. From 1999 to 2003 the relative sampling intensity for all inshore areas in the Gulf of Maine were designated as “high”, however from 2003 to 2007 these same areas were designated as “moderate”. This change in designation is not related to a decline in sampling effort within the inshore portion of the Gulf of Maine, it is due to the fact that the quartile scale changed because of the greatly improved sampling in offshore areas.

In general fisheries dependent sampling in all three stock units needs to be improved given the importance of the U.S. lobster fishery. Recent improvements in sampling offshore areas are in jeopardy because of a loss of funding for this program. Fisheries dependent data are critical to the accurate characterization of mortality rates and stock size and as such steps need to be taken to ensure that long term monitoring programs are maintained and enhanced.

5.1.2.3 Gapfilling and Expansions

To characterize the unknown length structure of harvested lobster, the length structure of available port and sea samples are applied to gap-filled landings. To account for biosamples “gaps” (months and areas for which landings were reported yet no/inadequate biosamples were taken), a number of adjustments and expansions were conducted using the following rules. Biosamples prior to 2004 (or 2003 for ME and NH) were gap-filled as described in Appendix 1 of ASMFC 2006.

Biosamples gapfilling rules:
Areas that had commercial landings without complementary size distribution data were filled by applying the size distribution from the next closest statistical area within that stock unit to the landings, or by applying the size distribution from the next closest year within that statistical area to the landings depending on availability of a representative set of biosamples.

As a result of poor data resolution in the offshore area, the ASMFC lobster technical committee was forced to characterize offshore landings from a very large area based on a limited number of samples, from disjointed time periods, and from a limited number of discrete offshore areas. This has the potential to introduce bias into fishing mortality estimates in areas that have a significant offshore component, such as Georges Bank. This problem was highlighted by the 2004 ASMFC lobster model review panel who stated “the data available are woefully inadequate for the management needs of this fishery, and that the primary limitation on the ability to manage is lack of data rather than choice of models.”

5.1.3 Development of Catch at Length Estimates

Landings and biological sampling data collected for this assessment spanned 1981-2006. Note that biological samples collected in 2006 were applied to preliminary landings reports for 2007 to obtain a rough estimate of catch-at-length by sex, month, and statistical area for 2007.

Once all landings data (recorded in lbs) were assigned an appropriate size distribution through biosamples gapfilling (section 5.1.1.3 above), they were expanded to total catch in numbers.

Steps in this expansion process are:

1. Average weight at length is computed for each sex, statistical area, agency, and time period (month/year combination) using the following carapace length-weight relationship from Estrella & McKiernan (1989) for all stock areas:

$$W = 0.000949 * CL^{2.9687} \quad \text{Females}$$
$$W = 0.000469 * CL^{3.1221} \quad \text{Males}$$

   These average weights are multiplied by the number of lobster sampled to obtain total sample weight for each agency, statistical area, and time period (month/year combination).

2. Sex ratio of the biosamples weights is calculated by dividing total female biosamples weight by the sum of male and female weights for each agency, statistical area, and time period. Sex ratio of the biosamples weights is used to apportion landed pounds by sex for each agency, statistical area, and time period.

3. To obtain the expansion factor from numbers landed to numbers landed at length, the number of lobster sampled in each 1 mm carapace length bin are divided by the total numbers of lobster sampled in each sex, statistical area, agency, and time period combination. This expansion factor is multiplied by total numbers landed to obtain the numbers landed at length for each sex, agency, statistical area, and time period.

5.1.4 Recreational Catch

The states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, and New York collect recreational information on lobster landings and is presented below. The recreational landings are generally only a few percent of the states total landings. Lobsters are mainly harvested by traps and diving recreationally. These landings were not included in the assessment due to their incomplete numbers and the difficulty in characterizing the length structure.

Maine

In 1997, a five trap recreational lobster license was established. The number of licenses issued has ranged from 467 in 1997 to 2118 in 2007. Since 2001, all license applicants must complete a 50 question exam on Maine lobster laws and lobster biology. A maximum of two recreational licenses may be assigned to each vessel. In 2008, a mandatory harvester logbook program was initiated, where 10% of each Maine Lobster Management Zone licenses were selected for trip level reporting.

New Hampshire

Recreational lobster fishing in New Hampshire represents those harvesters that fish with 5 traps or less with no sale of harvested lobster allowed. Recreational lobster harvest catch and effort data have been collected in the same manner as the commercial lobster harvest for inshore lobster landings. Between 1969 and 1985 mandatory annual reports from all lobster harvesters in state waters were compiled to produce annual lobster harvest totals. Between 1986 and 2005, a random selection (RSL) of a percentage of recreational licensed lobster harvesters and all new recreational entrants into the in-state lobster fishery were required to report catch and effort data. The reported data were expanded to reflect the total estimated inshore landings of lobster. The

RSL reports were submitted monthly and collected the following trip-level information: month and day fished, number of gear fished (both monthly and daily totals), area fished, average set over days/pot, weight of harvest, gear size, did fish or did not fish, and incidental catch. The reports submitted by new entrants were submitted yearly and represented monthly-summarized catch and effort information from New Hampshire inshore waters.

Beginning in 2006, all recreational lobster harvesters are required to report monthly-summarized harvest and effort data on an annual basis. Any recreational harvester may elect to use Electronic Harvester Reporting Program (EHTR) developed by New Hampshire Fish and Game to report trip-level data on a monthly basis. Recreational lobster catch in New Hampshire inshore waters from 1989-2007 averaged 0.5% (range of 0.2%-0.8%) of the total New Hampshire inshore lobster landings with licenses making up 32% (range of 26%-37%) of the total New Hampshire inshore lobster licenses.

Massachusetts
Basic recreational lobster catch and effort data (i.e. number of lobster harvested, number of traps fished) have been collected via the permit-renewal process since 1971. The report form was modified in 2007 to include an 'area-fished' component. Consequently, recreational catch and effort data are now available by stock area. In 2007, 11,034 recreational lobster permits were issued, of which 7,994 (72%) submitted catch reports (i.e. renewed their permit) and 5,834 of those individuals reported actually fishing for lobster. However, only 3,740 permit holders successfully reported the area in which they fished. Of those that reported area-fished, 81.7% reported fishing in the GOM stock area, 14.1% in the SNE stock area and 4.2% in the GB stock area. A total of 186,269 lobsters were reported harvested by recreational lobstermen in 2007. Of those that reported area-fished, 84.0% of the landings came from the GOM area, 12.0% came from the SNE stock area and 4.0% came from the GB stock area.

Rhode Island
Prior to the implementation of the Rhode Island / ACCSP catch/effort logbook data collection program in 1999, no catch/effort data were collected regarding the Rhode Island recreational lobster trap and lobster diver fisheries. Since 1999, recreational lobster trap and lobster diver license holders have been asked to provide their monthly lobster catch and effort data in a report that is submitted annually. The submission of recreational lobster catch/effort data is voluntary. During the period 1999-2007, RI recreational lobster landings have averaged 0.224% of the total RI lobster landings.

Connecticut
From 1983 to 1999, the recreational lobster fishery in Connecticut landed between 38 and 105 thousand lobster annually, equivalent to a maximum of 6% of commercial landings during those years. Since the mortality event that occurred in Long Island Sound in 1999, the recreational lobster fishery in Connecticut waters has landed 15-30 thousand lobster, equivalent to about 2% of commercial landings. Total pots fished recreationally declined from 4,000 - 9,500 in 1983-1999 to less than 3,700 since the die off in 1999. The number of license holders has also declined from 1,200–2,800 issued between 1983 and 1999 to 900-1,200 issued between 2000 and 2006. On average, 73% of recreational lobster license holders reported using their licenses between 1983 and 1999. Following the die-off, not only were fewer licenses issued, fewer license holders

reported fishing, with an average of only 50% actively fishing between 2000 and 2006. Approximately one in five license holders captured lobster recreationally while diving in Connecticut waters between 1983 and 1999. From 2000 to 2006, that number dropped by almost half, with approximately one in ten capturing lobster while recreationally diving. From 1983 to 1999, three in four active license holders set traps to capture lobster. Since 2000, the majority (average of 86% of active license holders) of recreational lobstermen in Connecticut fished for lobster with traps.

New York

Recreational lobster license holders are required to complete an annual Recall Landings Survey for the previous year when they apply for their current year's license. This data has been collected since 1998. New York recreational lobster landings from 1998 – 2007 averaged 0.4% (range of 0.1%-1.4%) of the total New York landings. The number of licenses ranged from 1,728 in 1998 to 882 in 2000. On average, 65% of the harvest was from traps and 32% from diving.

New Jersey

New Jersey collects no recreational landings data for American lobster. However, a recreational lobster pot permit is available which allows the permitee to fish up to 10 lobster traps in state waters. Hand-harvest by divers is also allowed and requires no permit; spearfishing for lobster is prohibited. Recreational harvesters may take no more than six lobster per day.

5.2 Fishery Independent Survey Data

5.2.1 Trawl Survey

Data used in this assessment were obtained from bottom trawl surveys conducted by the NMFS, Northeast Fisheries Science Center (NEFSC) on the continental shelf as well as from inshore bottom trawl surveys conducted by the states of Connecticut, Maine, Massachusetts, and Rhode Island. Information from the survey conducted by the state of New Jersey was also included, but not used in the models due to the low frequency of hauls with positive lobster catch. NEFSC, CT, MA, ME, and RI conduct trawl surveys during the spring and fall. More detailed information on survey area and timing, years surveyed, sampling design, gear, and methods for each survey is presented below. Refer to Table 5.2.1.1 for the relative sampling intensity of each survey.

5.2.1.1 Trawl Survey Methods

NMFS, NEFSC

The Northeast Fisheries Science Center bottom trawl survey began collecting lobster data in 1967(fall) and 1968 (spring). The fall survey is generally conducted in September and October. The spring survey is generally conducted in March to May. Lobster data used in this assessment are from the fall survey since 1982, prior to 1982 the lobster survey data have not been audited.

The NEFSC bottom trawl survey utilizes a stratified random sampling design that provides estimates of sampling error or variance. The study area, which now extends from the Scotian shelf to Cape Hatteras including the Gulf of Maine and Georges Bank is stratified by depth. The stratum depth limits are < 9 m, 9-18 m, >18-27 m, >27-55 m, >55-110 m, >110-185 m, and >185-365 m.

Stations are randomly selected within strata, the number of stations in the stratum being proportional to stratum area. The total survey area is 283,137 km^2. About 320 hauls are made per survey, equivalent to one station for about every 885 km^2.

Most survey cruises were conducted using the R/V ALBATROSS IV, a 57-meter (m) long stern trawler, however some cruises were made on the 47-m stern trawler R/V DELAWARE II. On most spring, and autumn survey cruises, a standard, roller rigged #36 Yankee otter trawl was used.

The standardized #36 Yankee trawls are rigged for hard-bottom with wire foot rope and 0.5 m roller gear. All trawls were lined with a 1.25 cm stretched mesh liner. BMV oval doors were used on all surveys until 1985 when a change to polyvalent doors was made (catch rates are adjusted for this change). Trawl hauls are made for 30 minutes at a vessel speed of 3.5 knots measured relative to the bottom (as opposed to measured through the water).

Maine

Trawl survey data has been limited historically in nearshore waters along the Maine coast. In 2000, a comprehensive inshore trawl survey was initiated along the coast of Maine and continues today.

In the fall of 2000, the Maine/New Hampshire inshore trawl survey was initiated. The inshore trawl survey is conducted during the spring and fall of each year, same as that of the NMFS offshore surveys. It is a stratified random design modeled after the NMFS and Massachusetts Department of Marine Fisheries (MADMF) surveys. The design includes four depth strata: 5-20 fathoms, 21-35 fathoms, 36-55 fathoms, greater than 56 fathoms (its outer boundary roughly delineated by the 12-mile limit), and 5 regions based on oceanographic, geologic, and biological features. The fourth stratum was added in the spring of 2003. It expands the coverage area to equal that area covered by the ASMFC and allows some overlap between this survey and the NMFS offshore survey area. It also slightly reduces the sampling pressure in the shallower strata, which has been of concern to fixed gear fishermen in the past. To randomize the survey area (~4,000 NM^2, square nautical mile), each depth stratum was divided into 1 NM^2 sampling grids. A target of 100 stations was selected for sampling in each survey resulting in a sampling density of about 1 station / 40 NM^2. This density compares to NMFS 1 station / 260 NM^2 and Massachusetts' 1 station / 19 NM^2. The number of stations per stratum was allocated in proportion to each stratum's area. When a station is encountered that cannot be towed, an alternate tow is selected nearby over similar depth.

For a full description of the gear please see Chen et al. (2005b). A standard trawl tow, 20 minutes duration, was made at each station. Shorter tow times were accepted under certain circumstances. Tow speed was maintained at 2.1 to 2.3 knots and tow direction was oriented toward the tidal current whenever possible. All sampling was conducted during the day. After each tow, the net was brought aboard and emptied onto a sorting table. All individuals were identified and sorted by species. All lobster were immediately separated and processed while the rest of the catch was sorted. Total weights (by sex), carapace length (mm), shell condition, presence and stage of eggs, V-notch condition, and trawl damage were recorded. All lobster were measured and are recorded in electronic format for analysis.

Results of the two surveys in the 1990s were presented for the first time in the 2000 assessment.

New Hampshire

Since the fall of 2000, the states of New Hampshire and Maine have been conducting an Inshore Bottom Trawl Survey in order to collect abundance and biological information on groundfish, lobster, and other marine organisms from the shore out to the 12-mile limit in the hopes of establishing a long-term fishery independent monitoring program. Refer to Maine's description of this independent survey for details.

Massachusetts

Since 1978, spring and autumn bottom trawl surveys of Massachusetts territorial waters have been conducted by the Resource Assessment Project of the Massachusetts Division of Marine Fisheries. The objective of this survey is to obtain fishery-independent data on the distribution, relative abundance and size composition of finfish and select invertebrates.

Methods

The survey utilizes a stratified random sampling design using 23 strata based on six possible depth zones (<30, 31-60, 61-90, 91-120, 121-180, and >180 feet) within five bio-geographic regions and includes Massachusetts Bay north to the Merrimac River and Cape Cod Bay (Gulf of Maine - GOM), east of Cape Cod and Nantucket/Nantucket Sound (outer Cape), and Buzzards Bay/Vineyard Sound (Southern New England - SNE). Approximately 100 stations are randomly predetermined each season and allocated to strata in proportion to each stratum's estimated area. Randomly chosen stations in locations known to be untowable due to hard bottom are reassigned. Sampling intensity is approximately 1 station per 19 square nautical miles. A minimum of two stations are assigned to each stratum in order to provide estimates of variance.

A standard tow of 20-minute duration at 2.5 knots is attempted at each station with a 3/4 size North Atlantic type two seam otter trawl (11.9 m headrope/15.5 m footrope) rigged with a 7.6 cm rubber disc sweep; 19.2m, 9.5mm chain bottom legs; 18.3 m, 9.5 mm wire top legs; and 1.8 X 1.0 m, 147 kg wooden trawl doors. The codend contains a 6.4 mm knotless liner to retain small fish. Abbreviated tows as short as 13 minutes are accepted as valid expanded to the 20 minute standard. The F/V Frances Elizabeth conducted the first eight surveys through fall 1981; the 72 foot NMFS R/V Gloria Michelle has been the survey platform for every survey since spring 1982. All tows are conducted during daylight hours.

Standard bottom trawl survey techniques are used when processing the catch. Generally, the total weight (nearest 0.1 kg) and length-frequency (nearest centimeter) are recorded for each species on standard trawl logs. Collections of age and growth material, and maturity observations are undertaken during the measuring operation.

Rhode Island

Rhode Island Department of Environmental Management (RIDEM) research trawl surveys began in 1968 and have been modified over time, but all data used in this assessment were collected with the same or similar gear. Initial sampling occurred at four fixed locations monthly; since 1977, surveys included a mixture of fixed and random sampling stations as well as spring and fall sampling. Sampling is conducted with a ¾ high-rise heavy-duty bottom trawl towed for 20 minutes at 2.5 knots. Sampling areas include Narragansett Bay and Rhode and Block Island Sounds. Collected data include carapace length, sex, shell hardness, presence of extruded ova, bottom and surface water temperature, sea conditions, and wind speed/direction.

URI has also sponsored a trawl survey since 1967 in Narragansett Bay (West Passage). Fixed sites are sampled weekly. Early work recorded total number and weights of lobster along with bottom temperature, but no size or sex information for individual lobster. Since May 1994, data collection has included sex, size, cull and molt status, and evident disease. Data from this survey were not used in this assessment and are not presented in this report because of compatibility constraints due to sampling design.

Connecticut

The CT Department of Environmental Protection Marine Fisheries Division has conducted a spring trawl survey in Long Island Sound since 1985 and a fall survey since 1984. The sampling gear employed is a 14 m otter trawl (9.1 m headrope, 14 m footrope) with 102 mm mesh in the wings and belly, 76 mm mesh in the tail piece, and 51 mm mesh codend towed at 3.5 knots for 30 minutes from a 12.8 m research vessel (1984-89) or the 15.2 m research vessel (1990-present). Forty stations are scheduled to be sampled monthly during a spring survey (April, May, June) and a fall survey (September and October) for a total of 200 samples annually. The trawl survey employs a stratified random sampling design with four depth strata (0-9 m, 9.1-18.2 m, 18.3-27.3 m, 27.4+m) and three bottom substrate types (sand, mud, and transitional). The sampling area is divided into 1.85 x 3.7 km (1 x 2 nautical mile) sites and includes all trawlable CT and NY waters west of New London and east of Greenwich, CT. Sampling intensity is one station per 68 km^2 (20 square nautical miles) or less.

Biological data recorded for each tow include total weight (1992- present), carapace length (mm), sex, shell hardness, relative fullness of egg mass, developmental stage of eggs, cull status, and any signs of shell damage (new or old) or disease. From 1992-98, pleopods were taken from a large number of females for cement gland staging to determine length at maturity.

Millstone Environmental Laboratory staff have conducted a research (ventless trap) survey since 1978 in the vicinity of Millstone Nuclear Power Station in eastern Long Island Sound (DNC 2008). Molt frequency, molt increment, shell disease, and temperature data were used in this assessment.

New Jersey

The New Jersey Division of Fish and Wildlife has conducted a groundfish survey along the New Jersey coast since August 1988. The survey area is about 1800 square miles of coastal waters between Sandy Hook, NJ and Cape Henlopen, DE and from a depth of 18 to 90 ft. The area is divided into 15 strata that are bounded by the 30, 60, and 90 ft isobaths. The survey design is stratified random. Since 1990, cruises have been conducted five times a year - in January, April, June, August, and October. Two 20-minute tows are made in each stratum, plus one more in each of the nine larger strata, for a total of 39 tows per cruise in all months except January, when the additional tows are omitted. The trawl gear is a two seam three-in-one trawl (so named because all the tapers are three to one) with 12 cm mesh in the wings and belly and 7.6 cm in the codend with a 6.4 mm liner. The headrope measures 25 m and the footrope 30.5 m. Rubber cookies measuring 2 3/8 inch in diameter are used on the trawl bridles, ground wires, and footrope. Five different vessels have been used to conduct the surveys to date. Data from this survey was utilized in alternative model runs, but not utilized for the primary model due to the low frequency of hauls with positive lobster catch.

5.2.1.2 Development of Abundance Indices

Stratified delta mean catch per tow at length by sex and stock unit was calculated on a 1 mm basis for the NEFSC, MA DMR, RI DEM, CT DEP, and NJ DFW spring and fall surveys (Pennington 1983). Stratified geometric mean catch per tow by sex was calculated for the ME DMR spring and fall surveys on a 1 mm basis. Survey data were tabulated differently for use in the CSM and University of Maine assessment models.

Collie-Sissenwine model

Recruits are lobster that are not legal size at the time of the survey but are expected to molt and grow to legal size during the next year. Post-recruits are legal size at the time of the survey. Together, recruits and post-recruits constitute the fishable abundance of lobster that will contribute catch to the fishery during the current year. Recruit and post-recruit abundance indices for lobster were calculated from survey catch at length (i.e. total delta mean numbers per tow prorated to one mm CL size groups based on stratified mean proportions in each length group). Note that a time series of recruit abundance indices for modeling will contain lobster of somewhat different sizes if the minimum legal size changed. For a detailed description of the index development see the 2006 ASMFC Lobster Stock Assessment section 5.3.1.3.

University of Maine model

Mean survey catch per tow at length in 1 mm intervals for lobster ≥ 53 mm were summed into 5 mm bins for each sex (Section 6.2). Ideally, means would be calculated using the same bin size assumed in the model. However, for this assessment agencies were not asked to provide their survey means at length in both 1 mm and 5 mm bins (for CSM and University of Maine models, respectively) due to time constraints.

5.2.1.2.1 Survey Index Trends

Generally, fishery-independent survey catches of lobster from Maine to New Jersey show an increase in the abundance of lobster from the early 1980s through the 1990s. Gulf of Maine and Georges Bank (Table 5.2.1.2.1 and Figures 5.2.1.2.1.1-5.2.1.2.1.2) indices have remained relatively high. Southern New England stock indices show an abrupt decline in the late 1990s remaining stable at very low levels thereafter (Table 5.2.1.2.1 and Figure 5.2.1.2.1.3).

In offshore Gulf of Maine waters, the NEFSC survey saw a rise in abundance in the 1990s, stabilizing at moderately high values in 2000-2004 (Figure 5.2.1.2.1.1). Indices in 2005-2007 increased in the spring survey but decreased in the fall survey. Coefficients of variation for this survey ranged from 12-65 (median fall=26, median spring=24). In southerly near-shore GOM waters, the Massachusetts survey showed above average abundance in the 1990s, followed by a decreasing trend for 2001-2004. Indices for 2005-2007 were variable. Coefficients of variation for this survey ranged from 5-73 (median fall=33, median spring=29). The relatively short time series generated by the Maine survey in northerly near-shore waters shows no trend; lower values in 2003-2004 were followed by somewhat higher values in 2005-2007 for both seasons. Coefficients of variation for this survey ranged from 15-22 (median fall=19, median spring=17).

The Georges Bank NEFSC survey indices show little variability over the time series (1982-2007) for both seasons except for a single spike in the fall of 2002. Indices for 2005-2007 are above median values. Coefficients of variation for this survey ranged from 10-77 (median fall=22, median spring=38).

In Southern New England waters, all three state surveys of inshore waters (Rhode Island, Connecticut, New Jersey) and the NEFSC survey of offshore SNE waters show a rise in abundance in the 1990s followed by a decline to very low values of both size groups after 1998 (Figure 5.2.1.2.1.2). Fall abundance trends for all surveys are significantly correlated (ts=0.49-0.62, df=18-23, p=0.02-0.04) except for NEFSC versus NJ surveys (ts=0.34, df=18, p=0.17). However, trends recorded in the New Jersey fall survey correlate with Connecticut and Rhode Island trends (ts=0.55-0.60, df=18, p<0.01). Fall surveys show a synchronous rise from 1990-1997 and decline from 1998-2002. All remain at the lowest values for 2003 -2007 except for RI indices which show a modest increase in 2006-2007. Spring indices vary widely but are all generally higher in the 1990s and lower after 1999. Over the time series, coefficients of variation for NEFSC survey ranged from 6-77% (median fall=32%, spring=53%); 21-79% for the RI survey (median fall=37%, spring=30%); 16-38% for the CT survey (median fall=23%, spring=20%); and 26-57% for the New Jersey survey (median fall=45%, spring=39%).

5.2.1.2.2 Size Structure of Survey Catches

Size compositions of lobster taken in fall research trawl surveys were compared for animals 53mm CL and greater. Median lengths for NEFSC Survey catches in Gulf of Maine waters (Figures 5.2.1.2.2.1-5.2.1.2.2.2) varied without trend from 1981-2007 for males, while showing a slight increase from 2003-2007 for females. Median lengths for the ME survey (Figures 5.2.1.2.2.3-5.2.1.2.2.4) catches in inshore waters varied without trend for both sexes, but reflect only an 8-year time series from 2000-2007. Median lengths for the MA survey catches (Figures 5.2.1.2.2.5-5.2.1.2.2.6) also varied without trend from 1981-2003 for males, while showing a slight decrease from 2005-2007 for females. Median lengths for NEFSC Survey catches on Georges Bank (Figures 5.2.1.2.2.7 and 5.2.1.2.2.8) varied without trend through the 1990s, and then increased for females to over 120mm CL in 2006 and over 100mm CL for males in 2005. Median lengths for 2007 catches returned to earlier values. Georges Bank spring survey data show similar increase median lengths in recent years Figures 5.2.1.2.2.9 and 5.2.1.2.2.10, but the 2007 size continued to rise. In Southern New England, median values in the offshore NEFSC survey (Figures 5.2.1.2.2.11 and 5.2.1.2.2.12) ranged more widely than median values for catches in the two inshore surveys in Connecticut/New York (Figures 5.2.1.2.2.13 and 5.2.1.2.2.14) and Rhode Island (Figures 5.2.1.2.2.15 and 5.2.1.2.2.16) waters. Median lengths and frequencies of the catch in all three SNE surveys show no trend for either sex over the time series.

5.2.2 Ventless Trap Survey

The ASMFC coast-wide ventless trap survey was initiated in 2006 and expanded in 2007 with the intention of answering the need for a standardized fishery-independent survey designed specifically to monitor lobster relative abundance and distribution. This need was specifically identified in the 2004 Lobster Stock Assessment (ASMFC 2006). Of all the possible methods for surveying lobster populations, traps have the fewest associated limitations in relation to habitat factors because they can be used on complex substrate (Smith and Tremblay 2003), A number of factors influence their catchability, which can be difficult to interpret. In pilot surveys conducted by MADMF using a stratification scheme that incorporated depth and substrate type, depth was found to be the driving environmental factor in patterns of catch and size distribution (MADMF unpublished data).

5.2.2.1 Ventless Trap Survey Methods

The ASMFC ventless trap survey employed a random stratified survey design, using Statistical Area and depth as the strata classifications. The Statistical Areas (statistical area) included in the survey were 511, 512, 513, and 514 in the Gulf of Maine stock, and 538, 539, and 611 in the Southern New England stock unit. The survey was a cooperative effort between state fisheries agencies and commercial lobstermen, who were contracted to fish at pre-determined sampling locations along the New England coast from Maine to New York.

The areal extent of the survey encompassed the state waters portion of Maine, Massachusetts, Rhode Island, Connecticut, and New York. For sampling logistics the following areas were excluded from the study area; a) In Maine (statistical area 511, 512, 513), the estuaries associated with the Kennebec and Penobscot Rivers, b) in Massachusetts (statistical area 514), the southwest corner of Cape Cod which contains expansive shallow sandy flats, c) in Rhode Island, the western portion of Block Island Sound, and d) in New York and Connecticut, to Fisher's Island Sound. USGS bathymetry maps were used to identify depth strata. The survey design used three depth strata that span the range of depths in which lobster are typically fished in inshore waters: 0 - 20 m, 21 - 40 m, and 41 - 60 m. A bathymetry map of the study area was overlaid with a one minute latitude/longitude grid, and each grid cell was assigned a strata based on its bathymetric attributes. A fixed number of sampling stations (grid cells) were randomly selected within each strata in each Statistical Area, and new stations were selected each survey year.

In every state except Maine, each station was sampled with one six-pot trawl, in which vented and ventless lobster traps were alternated (3 of each per trawl). Maine deployed the gear either as two three-pot trawls (alternated traps similar to the other states and set end-to-end) or as a one six-pot trawl. Stations were sampled twice per month with a three night soak time between baited hauls on the following schedule:

	2006	2007
Maine (Areas 511, 512, 513)	June - Aug	June - Aug
Massachusetts (Areas 514, 538)	July - Aug (514), June - Aug (538)	June - Sept (514), May - Nov (538)
Rhode Island (Area 539)	July - Sept	June - Aug
New York (Area 611)	Sept - Nov	June - Sept

The different timing from state to state was intended to encompass the major molting period in each area and was somewhat impacted by funding availability.

Trap deployment, maintenance, and hauling were contracted to commercial fishermen. Fishermen were required to haul survey gear on as close to 3 day soak time as possible in an attempt to standardize trap catchability among sampling trips. All trawls were reset in the same assigned location each time. All traps used in the survey were of a standard design with dimensions 40" x 21" x 16" a single parlor, and 5" entrance heads. The size of the escape vent in vented traps was 1 15/16" in all GOM areas. In SNE the escape vents in vented traps were not completely standardized among statistical areas. In statistical area 538 1 15/16" escape vents were used in both years, in statistical area 539 2" vents were used in 2006, then 1 15/16" in 2007, and in NMFS statistical area 611 2" vents were used in both years. The lack of standardization of vent sizes among sub-areas could potentially bias CPUE estimates of both sublegal and legal lobster. However, the vast majority of lobster caught in the survey are caught in ventless traps, which dominate CPUE estimates in all areas. As such, the extent of any bias associated with unstandardized escape vents among sub-areas is likely to be very minimal. At-sea samplers (agency staff members) recorded catch in number of lobster, number of trap hauls, set-over-days, bait type, trap type, and for each lobster; carapace length (to the nearest mm), sex, shell hardness, culls and other shell damage, external gross pathology, mortality, the presence of extruded ova on females (ovigerous) and shell disease symptoms. Trap locations were confirmed with assigned station coordinates after each haul via GPS.

As the survey is still in its early stages, the data presented here for 2006 and 2007 have not yet been developed into an index of abundance. This is the goal as the time series is extended.

5.2.2.2 Ventless Trap Survey Results

Gulf of Maine

In 2006, the ventless trap survey sampled 20,245 lobster in the Gulf of Maine, and 36,869 in 2007 with 2,660 and 7,222 total trap hauls, respectively (Table 5.2.2.2.1). The larger number of lobster sampled in 2007 was due to an increase in survey effort. Eighty-nine percent of the catch was sublegal in 2006, and 92% was sublegal in 2007. Ninety-one percent and 85% of the legal-sized catch was within one molt of minimum legal size in 2006 and 2007, respectively. The size distribution of the catch (Figure 5.2.2.2.1) clearly illustrates the truncated size distribution of lobster in the Gulf of Maine.

In 2006, most stations in each statistical area had an average of 0.26 - 5 or 0.5 -1.0 legal lobster per trap haul (Figure 5.2.2.2.2). Statistical area 512 had the highest variability in average CPUE across its 25 sampling stations, with 8% of the stations having less than .025 legal lobster per trap haul and 4% of its stations having a high of 1.5 – 2 legals per haul. Statistical area 511 and statistical area 513 had several stations with a high CPUE of 1 – 1.5 legals per haul. Statistical area 514 had no stations with CPUE higher than 1 legal lobster per haul, and 20% of the sampling stations in statistical area 514 had less than 0.25 legals per haul. The area near the border between statistical area 513 and statistical area 512 appeared to have a concentration of stations with higher catch rates (ranging from 1.0 to 2.5 lobster). Another concentration of stations with moderate to high catch rates was present in the northeastern portion of statistical area statistical area 511.

In general, 2007 saw a shift toward fewer legal lobster per trap haul (Figure 5.2.2.2.3). Most sampling stations had 0.26-0.5 legal lobster per trap haul, and every statistical area except 512 had 20-30% of its sampling stations fall in the lowest catch bin (<0.25 lobster). The concentration of stations with relatively higher catch rates around the border of statistical area 513 and statistical area 512 persisted in 2007. However, the concentration of stations in the northeastern portion of statistical area 511 with higher catch rates did not persist. This may have been an artifact of the redistribution of sampling stations and highlights the need for an extended time series of randomly selected stations in order to understand spatial patterns in the catch data.

Overall, in 2006 there was a high degree of spatial variability in the CPUEs of sublegal lobster, with a low of 0.33 per trap haul at a station in statistical area 514 and a high of 17.33 per haul at a station in statistical area 511 (Figure 5.2.2.2.4). Most sampling stations in statistical area 511, 512, and 513 averaged 5-10 sublegals per trap haul, but in statistical area 514, most of the stations averaged only 1-5 sublegals per trap haul. In general, the catch of sublegal lobster seemed lower in the southern portion of statistical area 513 and in statistical area 514 than along the rest of the coast. Statistical area 514 was the only area to have average catch rates of less than one sublegal lobster per trap haul.

Similar to the legal-sized catch, there was also an overall shift to fewer sublegal lobster per trap haul in 2007 (Figure 5.2.2.2.5). Statistical area 512 and statistical area 514 had several stations with an average CPUE below one lobster per trap haul. In statistical area 512, these stations seemed to be concentrated inside Penobscot Bay, while in statistical area 514 they were distributed throughout Massachusetts' waters. However, while statistical area 513 had no stations with CPUEs greater than 5-10 sublegals in 2006, 10% of its stations in 2007 had average CPUEs of 15 – 25 sublegal lobster per trap haul (the highest observed average CPUE throughout the entire ventless survey, both years).

Southern New England

In Southern New England the ventless trap survey sampled 8,021 lobster in 2006 and 12,894 lobster in 2007. These lobster were observed over the course of 1,748 (2006) and 3,560 (2007) trap hauls (Table 5.2.2.2.2). The larger number of lobster sampled in 2007 was due to an increase in survey effort. Ninety percent and 89% of the catch was sublegal in 2006 and 2007 respectively. Most of the catch was within one molt of minimum legal size, 97% and 95% in 2006 and 2007 respectively. The size distribution in Southern New England was also truncated, and there were very few large lobster observed (the largest lobster observed in two years of sampling was 116 mm) (Figure 5.2.2.2.6).

Aside from statistical area 611, in which 100% of the stations averaged fewer than 0.25 legal lobster per trap haul, there was a broad range of legal CPUE across sampling stations in 2006 (Figure 5.2.2.2.7). While most stations in statistical area 538 and 539 averaged less than one legal lobster per haul, 12% of 538 stations and 4% of 539 stations had catch rates of 1.5 – 2.5 legal lobster per haul.

In 2007, the average CPUE at stations in statistical area 611 improved in general, with one station in eastern Long Island Sound averaging 1.5 – 2.5 legal lobster per trap haul (Figure 5.2.2.2.8). However, this improvement in average CPUE may have been related to the re-distribution of sampling stations, and half of the stations in 611 still had CPUEs below 0.5 legal lobster per haul. More than half the stations in statistical area 538 had very low CPUEs of legal lobster, below 0.25 per trap haul. In contrast, more than half of the stations in statistical area 539 had an average CPUE greater than 0.5 legal lobster per haul

Most of the sampling stations in statistical area 538 and statistical area 539 averaged 1-5 sublegal lobster per trap haul (Figure 5.2.2.2.9). Statistical area 611 had an equal percentage of stations averaging 1-5 and 5-10 sublegal lobster. The stations with higher CPUEs in statistical area 538 and statistical area 539 were concentrated near the mouths of Buzzards Bay/Vineyard Sound and Narragansett Bay, regions with deeper waters and slightly more bottom complexity.

In 2007, most of the sampling stations in statistical area 538 and statistical area 611 had lower CPUEs of sublegal lobster, falling into the two lowest CPUE bins (< 1 and 1-5) (Figure 5.2.2.2.10). However, average CPUE in statistical area 539 as a whole improved slightly from 2006, with a higher percentage of stations averaging 5-10 sublegals per haul.

There was a high degree of spatial variability in lobster catch rates throughout both the Gulf of Maine and Southern New England survey areas. This variability was likely related to variability in habitat complexity, including such parameters as substrate type and patchiness, water temperature, bottom currents, and water quality among others. A high resolution survey with random station selection is necessary in order to accurately capture this variability and produce robust estimates of relative abundance. Conducting the survey over a broad time frame, with bi-monthly sampling, accounts for temperature related differences in the availability of lobster to the survey gear. The ventless trap survey is the first standardized fishery-independent survey to sample for lobster across all possible habitat types over an extended time frame, which produces a more accurate picture of lobster relative abundance. Continued development of this time series will be invaluable to the assessment process. Improvements in the level of methods standardization from state to state will further enhance the utility of the dataset. Issues related to gear efficiency, trap saturation, and the descending limb of trap selectivity should be examined in the future.

5.2.3 Settlement Indices

The youngest benthic life stage for which quantitative data exist is for late-stage larval and newly settled lobster. Ovigerous female lobster hatch eggs in the summer and the larvae follow with a 6-8 week planktonic life phase (Ennis 1995). This planktonic phase is sampled by surface plankton nets towed at fixed stations in western Long Island Sound Giannini 2008) and gantry-mounted in power station outfall (DNC 2008). Although all stages of larvae are captured, only late stage (stage 4) larvae are used as a production index. After settlement to the bottom, the newly metamorphosed lobster can be sampled by divers using suction samplers (Wahle and Incze 1997). A standardized survey of this type has been conducted at stations in mid-coast Maine since 1989 and Rhode Island since 1990. Settlement data were provided by Rick Wahle, Bigelow Laboratory for Ocean Sciences, W. Boothbay Harbor, ME.

Settlement was measured by taking suction samples (Wahle and Steneck 1991) of natural cobble substrates. Settlement strength was defined as the abundance of newly settled lobster (0+ year class: <10 mm CL in ME, <13 mm CL in RI) in cobble nurseries after the end of the settlement season.

Density estimates of newly settled lobster were investigated for evidence of variability in regional settlement strength and for temporal trends that could be used at some point to predict landings in the fishery. This approach has been used successfully for the western Australian rock lobster, *Panulirus cygnus*, fishery (Phillips and Booth 1994). The Australian fishery predicts nearly 75% of their landings based on the long-term relationship between the settlement of the puerulus (the pelagic, postlarval stage) on artificial collectors and the size of the commercial catch four years later.

Observations of settlement patterns in Maine indicate coherent trends among sites in the same region across years (Palma et al. 1999). The similarity in trends in ME suggests that factors affecting settlement success vary on a regional basis, a finding which enhances the possibility that annual sampling could provide sufficient data for documenting temporal changes in regional year class size when first established and, possibly as they reach fishable size.

Maine data suggest that settlement was low and below the 25th quartile in three of five years during the period of 1995 to 2000. Since 2001, settlement densities have returned to values above the median and in many cases well above the 75th quartile. Settlement indices in Rhode Island were high in 1990 and 1991 but declined thereafter with 2004-2007 below the median (Table 7.5.2.3.2). CT larval indices corroborate good production in the Southern New England stock through 1999, followed by very low production from 2000-2007 with the one exception good production in western Long Island Sound in 2007. Indices for both eastern and western Long Island Sound (DNC Millstone Entrainment annual densities and CT DEP Survey annual densities, respectively) showed only two of eight years had larval densities above the 24-year median (1984-2007). The 2005-2007 averages for all three indices were between median and 25th percentile values for the time series.

Earlier studies have demonstrated that annual differences in the abundance of newly settled young-of-year lobster reliably foretell the number of 1-year-olds in the nurseries a year later (Wahle and Incze 1997, Wahle et al. 2003). The extent to which trends in settlement will eventually affect landings in any given year depends on the survival of juvenile lobster after settlement, variability in their growth, and the number of year classes that contribute to the size group that recruits into the fishery. The probable mixing of year classes in recruit size classes dampens year-to-year fluctuations in recruitment that would otherwise be caused by variable settlement densities. If settlement relates to the harvestable stock in future years, a decline in recruitment to the fishery would be expected in the Gulf of Maine. The declining pattern of larval production and settlement in Southern New England would also predict low levels of recruitment to the fishery in coming years.

6.0 Model Methods

6.1 Collie-Sissenwine Model (CSM)

The Collie-Sissenwine model (a.k.a. "modified DeLury" in ASMFC 2000) has been the primary assessment model in recent lobster stock assessments (ASMFC 2006). The CSM was used in this assessment to provide continuity with past assessments.

6.1.1 Methods

In CSM for lobster, recruit abundance (R_t) is the number of sublegal size individuals alive at the start of a year that would grow to legal size and recruit to the fishery during the year. Post-recruits (P_t) are the number of legal size individuals alive at the start of the year. Catch data are assumed to be accurate in CSM and survey data are assumed to have lognormal measurement errors. Mortality rates are for the total stock $N_t = R_t + P_t$. Natural mortality rates in each time step (M_t) are specified as input data and may vary over time. Abundance index data are assumed to measure abundance of recruits and post-recruits at the beginning of the year. The "survey years" are the annual period used in CSM modeling. The "q-ratio" (a selectivity parameter for abundance index data, see below) is assumed known and specified by the user).

The last (most recent or "terminal year") estimates are among the least precise in most stock assessment models. Recruit abundance is estimated in CSM for the terminal year but the estimate is just the recruit index for the last year scaled up to population abundance (the terminal recruit index is not included in goodness of fit calculations and there is no residual). Post-recruit abundance in the last year is probably more reliable because it is based on more years of data, estimated with a residual, and included in goodness of fit calculations. Total abundance for the terminal year is not reliable for lobster because recruits comprise the stock in most areas.

<u>Abundance and fishing mortality</u>

The current version of CSM uses one relative abundance index (e.g. a time series of mean numbers per tow from a bottom trawl survey) for recruits and one relative abundance index for post-recruits in each year. The relationship between absolute abundance of post-recruits and relative abundance of post recruits (p_t) measured by abundance data is:

$$p_t = qP_t$$

where is q is a scaling parameter or "catchability coefficient". The relationship between absolute and relative abundance of recruits is:

$$r_t = q\phi R_t$$

where the q-ratio ϕ measures catchability of recruits relative to post-recruits. Relative catchability in this context is equivalent to the survey selectivity or the survey partial recruitment vector in other models.

This and the 2006 assessment used "exact" exponential mortality calculations in place of the Pope approximation used in older assessments. Based on the exponential mortality model and relationships between stock and abundance indices, population dynamic calculations in CSM are carried out in units of relative abundance:

$$p_{t+1} = n_t e^{-Z_t + \varepsilon_t}$$

Where $n_t = \left(p_t + \frac{r_t}{\phi} \right)$, F_t, M_t, and Z_t=F_t+M_t are instantaneous annual rates for fishing, and ε_t is an optional process error that may represent variability in natural mortality or other biological factors not explicitly included in the model. F_t is calculated by trial and error so that $C_t = \frac{F_t\left(1 - e^{-Z_t}\right)qn_t}{Z_t}$ where C_t is the observed catch data.

Goodness of fit

In the CSM, a Levenberg-Marquardt algorithm is used to find parameter estimates (R_t, P_1, q, and ε_t) that minimize a weighted sum of squares. For lobster and a CSM model with N years of abundance index data, there were N +1 parameters to estimate (i.e. N -1 recruit parameters plus one initial post-recruit abundance parameter plus one survey catchability parameter). The number of abundance index observations used to estimate parameters is N-1 (for recruits) + N (for post-recruits). Process errors are no longer used in CSM.

The weighted sum of squares used to measure goodness of fit is:

$$\Re = \lambda_\eta \sum_{t=1}^{n-1} \eta_t^{\ 2} + \lambda_\delta \sum_{t=1}^{n} \delta_t^{\ 2}$$

where the user-specified weights (λ_η, λ_δ) are for residuals stemming from independent measurement errors in abundance index data for recruits (η) and post-recruits (δ). Simulations indicate that correlation between recruit and post-recruit indices in the same year has little effect on model estimates. Assuming lognormal measurement errors, recruit survey residuals in CSM models for lobster were:

$$\eta_t = \left[\ln(r_t) - \ln(\tilde{r}_t)\right]$$

Measurement error residuals for post-recruits are calculated in an analogous manner.

Blending Procedure for Stock Regions Not Covered by One Survey

The blending procedure applied in the 2000 and 2006 assessments (ASMFC 2000, 2006) was not used for this assessment. For this assessment, bootstrap estimates were only used to develop target reference points, as in ASMFC 2006. To obtain CSM abundance estimates for combinations of sex and sub-stocks, the NLLS estimates for each component were added. To obtain fishing mortality estimates, catches for each sex and sub-stock were summed to calculate annual catch. Fishing mortality (F) for combined sex and sub-stocks was calculated by iteratively solving the catch-equation.

Bootstrap procedures were used to characterize uncertainty in CSM estimates and in calculating target reference points (ASMFC 2006). To calculate variances for aggregated sex and sub-stock abundance estimates, bootstrap abundance estimates for each component were summed to obtain a set of bootstrap estimates for the aggregate in each year. To calculate variances for aggregated sex and sub-stock F estimates, we calculated bootstrap F estimates by solving the catch equation using total catch in each year and each set of annual bootstrap abundance estimates.

6.1.2 Configuration of CSM

All CSM runs for lobster in this assessment used fall survey years (October-September) because: 1) fall survey data generally provide the best estimates of relative abundance; 2) the current version CSM does not simultaneously accommodate multiple surveys for recruits or post-recruits; and 3) when using the catch equation in CSM, surveys are assumed to occur at the beginning of the year. Fall survey data are generally considered most reliable because water temperatures that effect lobster catchability are relatively warm and less variable in the fall (ASMFC 2000).

Time periods covered by CSM runs for lobster in this assessment were fall survey years 1984-2007 for SNE and fall survey years 1982-2007 for GOM and GBK. These periods include all years with consistent and reliable landings and survey data. These periods were used for computing average, median, and quartile estimates. Landings data were available for the 1982 – 2006 survey years.

CSM runs were for either females only or males only because of differences between the sexes in population trends, management measures, growth parameters, and because the current version of CSM does not accommodate both sexes simultaneously.

Abundance estimates for female and male lobster combined were calculated by summing CSM abundance estimates for both sexes. Fishing mortality estimates for males and females were calculated by using the catch and abundance estimates to solve for F.

<u>**Stock regions and survey areas**</u>

Lobster in GOM, GBK, and SNE stock assessment regions were modeled separately because of differences among regions in population trends and biological parameters. For modeling, it was necessary to break GOM and SNE stock assessment regions down further into "survey areas" because neither stock region is covered by a single bottom trawl survey. Bottom trawl surveys conducted by CT, RI, and the NEFSC have minimal overlap but, as a group, cover most of SNE region. Similarly, surveys conducted by MA and NEFSC cover most of the GOM region. On this basis, CSMs were applied to the GOM-MA and GOM-NEFSC survey areas in the Gulf of Maine and to the SNE-CT, SNE-RI and SNE-NEFSC survey areas in SNE. Abundance and fishing mortality estimates for the entire GOM or SNE stock assessment regions, as well as combined sexes were calculated as described above.

<u>Survey bottom trawl data</u>

Stock regions are defined by the survey strata used to tabulate abundance index data. For lobster in this assessment, the recruit and post-recruit indices were from the same bottom trawl survey with recruits and post-recruits distinguished by the legal size in each year, which varied over time and among areas and regions. Post-recruit indices were the delta-mean number of legal size lobster. Recruit indices were based on abundance of sublegal lobster in the survey and assumptions about the length-, region- and sex-specific probability of growing to legal size during the next 12 months. Survey data for recruits and post-recruits were given equal weight in parameter estimation (λ_η=λ_δ=1). The abundance index for male post-recruits in the RI fall survey during 2002 was zero because no lobster were captured. Zeroes are not allowed in CSM and were filled by averaging survey data from adjacent years.

<u>Landings</u>

Sex-specific landings data for lobster (numbers landed) were available by month for relatively large statistical reporting areas that do not coincide with survey areas. For modeling, landings in statistical areas were assigned to stock regions and survey areas based on spatial overlap and familiarity with the fishery.

Landings data for the terminal year (2006) were imprecise because official statistics were complete only through the end of calendar year 2006 and included only the first quarter of survey year 2006. To make full use of 2006 bottom trawl survey data in modeling, landings during 2006 were approximated as c/p where c was landings during October-December 2006 and p was the average percent of survey year landings during October-December (Table 6.2.6). It was important to use data for 2006 to make abundance and fishing mortality estimates for 2005 as reliable as possible.

<u>Assumed parameters</u>

Following ASMFC (2000), the assumed natural mortality rate was M=0.15 y^{-1} in all years. Following the review in ASMFC (2000) q-ratios (which measure survey catchability of recruits relative to post-recruits) were assumed to be 0.5 for NEFSC surveys and 1.0 for Connecticut, Rhode Island and Massachusetts. Although many factors affect q-ratio assumptions (ASMFC 2000), in brief, state surveys are carried out in coastal areas where small lobster may be relatively common and with bottom trawls equipped with bottom gear that make capture of small lobster more probable. NEFSC surveys, in contrast, are carried out further offshore with relatively large roller gear that is probably less efficient for small lobster.

6.2 University of Maine model

The University of Maine model was modified from Chen et al. 2005a for this assessment by Dr. Chen, his students, and the Lobster Stock Assessment Subcommittee to include a number of modifications described below. The most important modification was use of traditional instantaneous mortality rates in place of exploitation rates in calculations. In addition, new abundance and exploitation measures (described below) were calculated and used to describe trends and overall levels of abundance and fishing pressure to managers. Also, dynamic (for GBK) and static min/max binning procedure were developed for GOM and SNE. The University of Maine model includes a large number of features and options that were not used in this assessment and therefore not mentioned below. Maximum likelihood was used to estimate parameters in this assessment although the model also accommodates Bayesian statistical methods. The model was modified to generate database output. R language software was written to read the database output, produce model diagnostics, tables, and figures.

The University of Maine model was written in C++ using AD-Model Builder libraries and software. Models for GOM and SNE were two-sex models with separate population dynamics for females and males. The model for GBK was a single sex model with males and females combined. Program code for GBK was very similar but modified for use with a single sex (male and females combined). The model was modified to generate database output. R language software was written to read the database output, produce model diagnostics, tables and figures.

Other differences among stock unit models were due mainly to regional differences in data availability (Section 6.3). All three models covered 1982-2007. Estimates of 2007 catch-at-length were generated using 2006 biosamples data (Section 5.1.3). The GBK model extended estimates to 2008 to make use of 2008 spring survey data, which were not used in the other stock areas. Model estimates for 2008 are not presented.

Population dynamics

A bin size of 5 mm CL was used in the model so all lobster that molt will move out of their original size bin. Tagging data indicates that the smallest growth interval for lobster 50+ mm CL is about ~7 mm) minus a standard deviation of 2.3 mm (ASMFC 2006 Table 2.2.2.1). There were 35 size bins (53-223 mm CL) and the last bin was a plus group. Size bins are identified by their lower bound so that, for example, the 53 mm size bin contains lobster 53-57 mm CL.

The number of lobster in each size group at the beginning of winter during the first year in the model was:

$$N_{s,t=1,q=1,k} = N_{s,y=1} p_{s,t=1,q=1,k}$$

where $N_{s,t,q,k}$ is the number and $p_{s,t,q,k}$ is the corresponding proportion of abundance for sex s, year t, quarter q and length bin k. $N_{s,t}$ is total abundance for one sex at the beginning of the year and initial abundance of males and females (initial abundance of males and females are parameters estimated in the model). The proportions $p_{s,t,q,k}$ were equilibrium values calculated using a per recruit model at mortality levels similar to estimated mortality at the beginning of the assessment model.

After the initial quarterly time step in the model, abundance was calculated:

$$N_{s,t,q} = P_{s,t,q-1} G_{s,q-1} + R_{s,t,q}$$

where $P_{s,t,q-1}$ (a vector with one cell for each size group) are the survivors at the end of the previous quarterly time step, $G_{s,q}$ is the sex- and season-specific growth, and $R_{s,t,q}$ (a vector with entries ≥ 0 for the first three size groups only) are recruits. A vector of zeros was used for recruitment at the beginning of winter and spring because recruitment was assumed to occur only during summer and fall.

Survivors in each quarterly time step were calculated:

$$P_{s,t,q,k} = N_{s,t,q,k} e^{-Z_{s,t,q,k}}$$

where $Z_{s,t,q,k}$ is an instantaneous quarterly mortality rate that includes mortality due to fishing and natural causes. As described below, total, fishing and natural mortality rates in the model may vary among years, quarters, sexes, and size groups.

Growth was modeled using sex- and season-specific growth transition matrices $G_{s,q}$ calculated by simulation outside the assessment model. Growth occurs instantaneously at the end of quarterly time steps so that the growth transition matrix $G_{s,q-1}$ for quarter q-1 determines the size composition at the beginning the subsequent quarter q. The identity matrix was used for growth at the end of the fall and winter quarters because no growth occurs during winter and spring. Lobster recruit to the model at the beginning of the summer when growth from the major molt is assumed to occur and at the beginning of fall when growth from the minor molt is assumed to occur. New recruits of both sexes are assumed to molt into the first three CL bins (53, 58 and 63 mm for k=1 to 3) because the largest molt increment is 12 mm and the largest pre-recruit lobster (52 mm CL) would grow to no larger than 64 mm CL in a single molt. Proportions assumed recruiting into each of the first three size groups were 0.658, 0.334, and 0.007. These values are somewhat arbitrary but they describe a linear trend that terminates in a small value (0.007) and sum to one. The proportions were expected to decrease with size because relatively few large recruits could be expected togrow into the largest recruit size bin. This would only occur for large pre-recruit lobster that had relatively large growth increments). The proportions decrease with size because relatively few large recruits could be expected (growth into the largest recruit size bin would only occur for relatively large pre-recruit lobster that had relatively large growth increments). The total number of recruits (females and males) in each year (R_t) was:

$$R_t = \overline{\mathrm{R}}\mathrm{e}^{r_t}$$

where $\overline{R}$ is estimated average recruitment and r_t are estimated interannual deviations that represent year-to-year recruitment patterns. The proportion recruiting during summer was assumed to be 0.6615 and the proportion recruiting during fall was assumed to be 0.3385. In models for GOM and SNE:

$$R_{female,t} = \phi R_t$$

where ϕ is an estimated recruit sex ratio parameter. The negative log likelihood of the log scale recruit deviation parameters r_t was calculated assuming that they were independently and normally distributed with mean zero (i.e. with no spawner-recruit relationship) and variance calculated from the parameter estimates.

Recruitment deviations can be hard to estimate, particularly in the last year of the model. An optional user-specified additional constraint may be used in these cases. In particular, an additional log likelihood term is computed

$$\Delta = \sum_t \lambda_t \ln\left(R_t / \overline{R}\right)^2$$

where the annual weights λ_t are specified by the user. The weights λ_t were zero unless otherwise specified.

Survey trend data

The University of Maine model accommodates three surveys with quarterly- and sex-specific catches (i.e. a survey can include separate female and male catches with length data during the winter, spring, summer and fall). Both sexes and all four quarters share the same size-selectivity curve but use different survey catchability parameters (see below). Predicted values were calculated:

$$\hat{I}_{j,s,t} = Q_{j,s,q} \sum_{k} s_{j,k} N_{s,t,q,k}$$

where $I_{j,s,t}$ is the predicted value for survey *j* and sex *s* during year *t*, "hats" (^) indicate predicted values for data, $Q_{j,s,q}$ is a survey-, sex- and quarter-specific catchability parameter (see below), $s_{j,k}$ is a selectivity parameter for size group *k* (see below), and $N_{s,t,q,k}$ is abundance at the beginning of the quarterly time step.

Size specific survey selectivity in the University of Maine model relates size composition in the stock to length data from surveys. The same approach was used for commercial landings. In this context size selectivity includes effects selectivity due to gear design, overlap between the survey and stock, and size specific differences in capture efficiency. It was calculated:

$$s'_{j,k} = \frac{1}{1+e^{a_j\left(L_k - b_j\right)}} \frac{1}{1+e^{c_j\left(L_k - d_j\right)}}$$

$$s_{j,k} = \frac{s'_{j,k}}{\max\left(s'_{j,k}\right)}$$

where a_j, b_j, c_j and d_j are survey specific selectivity parameters and L_k is the size in mm at the middle of the length group *k*. Depending on the assumed or estimated values of the selectivity parameters, the selectivity curve will be either an ascending, descending or double logistic function. The calculated values $s'_{j,k}$ were divided by the maximum value so that the final survey selectivity curve had a maximum value of one.

The catchability parameters were calculated using a closed form maximum likelihood estimator for lognormal survey indices:

$$Q_{j,s,q} = e^{\frac{1}{n_{j,s,q}} \sum_{i} \ln\left(\hat{I}_{j,s,q,k} / I_{j,s,q,k}\right)}$$

where $n_{j,s,q}$ is the survey-, sex- and quarter-specific number of survey observations. Different survey catchability parameters were used for each sex and quarter in the same survey.

Goodness of fit for survey data was calculated assuming that the data were from a lognormal distribution with predicted values specified by the user. Typically, the variance of the logged survey series var[ln(*I*)] was used in initial runs with "tuning" in final runs to insure that the assumed variance and variance of residuals were similar.

Fishery size selectivity
Fishery selectivity was modeled based on four contributing factors: 1) legal sizes (minimum and maximum legal size); 2) gear characteristics (changes in size of escape vent requirements); 3) conservation measures (discards of v-notched and ovigerous lobster); and 4) “other” factors such as fishermen behavior, lobster behavior, market preferences, et cetera. Auxiliary information is available to characterize effects due to changes in legal sizes, gear characteristics and conservation measures (factors 1-3) so these factors were specified. Effects due to “other” factors (factor 4) can be estimated in the model. Commercial selectivity in the model changes whenever one of the underlying factors changes (e.g. management changes to legal size limits). In general, there were differences in commercial selectivity over time, between sexes, and among stock areas.

Commercial selectivity at size for each gender, year and quarter $u_{s,t,q,k}$ was computed:

$$u'_{s,t,q,k} = l_{s,t,k} g_{s,t,k} c_{s,t,q,k} o_k$$

$$u_{s,t,q,k} = \frac{u'_{s,t,q,k}}{\max\left(u'_{s,t,q,k}\right)}$$

Where the components for legal sizes ($l_{s,t,k}$) and gear ($g_{s,t,k}$) was the same for each quarter in a year but varied between the sexes and among years. The component for conservation discards ($c_{s,t,q,k}$) varied among quarters to potentially capture seasonal differences in discard of ovigerous females due to the seasonal reproductive cycle. The component for other factors affecting selectivity was the same for all sexes, quarters and years. The product of each factor was divided by the maximum value of the products so that the final fishery curve had a maximum value of one.

Preliminary models for this assessment estimated the other selectivity component as a lognormal term with estimated mean and variance. However, other selectivity estimates were imprecise and had little effect on model fit. In other words, factors 1-3 appeared sufficient to characterize commercial selectivity in this assessment. Therefore the “other” selectivity component was “turned off” by fixing it at one (o_k=1) for all size groups.

Survey and fishery size composition data
Predicted values for survey size composition data were calculated using the relationship:

$$\hat{p}_{j,s,t,k} = \frac{s_{j,k} N_{s,t,q,k}}{\sum_i s_{j,i} N_{s,t,q,i}}$$

Predicted fishery size composition data were calculated in the same manner but using fishery selectivity curves $u_{s,t,q,k}$ in place of survey selectivity curves $s_{j,i}$.

A robust (insensitive to outliers) negative log likelihood from Fournier et al. (1990) was used to calculate goodness of fit for survey and fishery size composition data. For a single set of size composition data (i.e. for one sex, one fishery or survey and during one quarter of one year):

$$\Lambda = 0.5 \sum_{i=k_{first}}^{k_{last}} \ln\left(2\pi\left(\xi_i + 0.1/N\right)\right)$$

$$+ \sum_{i=k_{first}}^{k_{last}} N \ln(\tau)$$

$$- \sum_{i=k_{first}}^{k_{last}} \ln\left(\frac{-e^{r_k^2}}{2\left(\xi_{,i} + 0.1/N\right)\tau^2} + 0.01\right)$$

where N=k_{last}-k_{first}+1 is the number of size bins in the calculation, $r_k = \hat{p}_k - p_k$ is the raw residual for size group k, $\xi = \hat{p}_k(1-\hat{p}_k)$ is an underlying variance, and τ is an inverse sample size parameter that scales the variance. In this model, τ=1/*S* where *S* was a user specified sample size. Fournier et al.'s (1990) robust log likelihood replaced a similar one used by Chen et al. (2005a).

The choice of the first and last size groups (k_{first} and k_{last}) used in calculating negative log likelihoods for size composition data may affect results because the model includes many size bins that typically have very low predicted proportions. Two approaches were used in this assessment to choose k_{first} and k_{last}. Both approaches treated k_{first} and k_{last} as plus groups so that

$p^*_{k_{first}} = \sum_{j=1}^{k_{first}} p_j$ and $p^*_{k_{last}} = \sum_{j=k_{last}}^{35} p_j$.

The dynamic binning approach used for GBK chose k_{first} and k_{last} for each set of length composition data such that the observed proportions in $p^*_{k_{first}}$ and $p^*_{k_{last}}$ were ≥ 0.01, an approach borrowed from the Stock Synthesis Model (R. Methot). With dynamic binning, k_{first} and k_{last} may vary from year to year for the same survey, sex and quarter.

The static binning approach used for SNE and GOM involved k_{first} and k_{last} values that were specified by the user for the fishery and for each survey. With static binning, one set of k_{first} and k_{last} values were used for all length data from the commercial fishery, another set for all length data from survey 1, etc. Static binning k_{first} was chosen so that $p^*_{k_{first}} \geq 0.01$ approximately in most years; k_{last} was chosen so that $p^*_{k_{last}} \geq 0.01$ for the year with the widest length distribution in order to provide the model with informative zero catches-at-length in years where the length distribution may have collapsed.

The relative performance of the dynamic and static binning methods was not formally evaluated; only informal comparisons of base case abundance and F estimates between binning approaches were conducted. However, the dynamic approach seemed to work well for GBK and GOM but not for SNE. Relative to other stock units, size data from SNE were truncated (absence of relatively large individuals) during periods with high mortality producing empty size groups that were presumably informative. Dynamic binning probably worked relatively well for GBK and GOM because more of the variation in maximum size observed was presumably due to sampling error than to changes in mortality rates.

Effective sample size for size data

The plausibility of user-specified sample sizes for catch-at-length data was evaluated using "effective" sample size (Methot 2000). Effective sample size (n_{eff}) is an estimate of the sample size that corresponds to the goodness of fit observed in preliminary models:

$$n_{eff} = Var(r)N \Big/ \sum_{j=k_{first}}^{k_{last}} \left[\hat{p}_j\left(1-\hat{p}_j\right)\right]$$

Sample sizes (S) assumed in initial model runs were crude (i.e. the number of positive tows in a survey during each year or the number of port samples during each quarter of each year). In final runs, assumed S values were "tuned" so that median S and median n_{eff} were approximately equal for each sex in each survey/fishery during each quarter. The same value of n_{eff} was generally used for all observations in a set for each sex during final runs (e.g. for all years of length composition data for males from the fall survey), but differed between surveys and among seasons for commercial data.

Landings

In the assessment model, predicted landings were calculated either in terms of total number or total weight. Total numbers landed were calculated:

$$\hat{L}_{s,t,q} = \frac{F_{s,t,q,k}}{Z_{s,t,q,k}} N_{s,t,q,k}\left(1-e^{-Z_{s,t,q,k}}\right)$$

where $F_{s,t,q,k}$ and $Z_{s,t,q,k}= F_{s,t,q,k}+ M_{s,t,q,k}$ are sex-, year-, quarter- and size-specific instantaneous mortality rates for quarterly time steps. Natural mortality $M_{s,t,q,k}$ could vary over time and among size bins but was generally assumed to be 0.0375 per quarter (0.15 per year).

Goodness of fit for landings data was calculated in the same manner as for survey trend data. Typically, the standard deviation was assumed to be between 0.05 and 0.15 to allow the model to estimate landings to some extent.

Parameter estimation

Parameters were estimated by minimizing the negative log likelihood:

$$\Xi = -\lambda_j \Lambda_j$$

where Λ_j is the negative log likelihood for data type or model component j and λ_j is a weighting factor. The weighting factors were one (λ_j=1) in final runs unless otherwise noted. Likelihoods and predicted values for each type of data and model component are described below.

Depending on the stock and model run, parameters estimated in this assessment for GOM and SNE were: 1) recruitment parameters (mean recruitment, annual recruit deviations and the sex ratio of new recruits); 2) initial abundance (number of females and males at the beginning of the first year in the model); 3) survey selectivity parameters; and 4) fishing mortality parameters for males and females during each quarter.

The majority of the estimated parameters were for fishing mortality. A model with 26 years (1982-2007), two sexes and three surveys would have to estimate at least 241-250 parameters

(28 recruitment parameters, 2 initial abundance parameters, 6-12 survey selectivity parameters, and 208 fishing mortality parameters). Models for GBK included 2008 but had fewer parameters because the sexes were combined. An analogous model for GBK would estimate at least 143-149 parameters.

Descriptors of abundance and fishing pressure

In this assessment, we use "reference abundance" and "effective exploitation" as the primary descriptors of annual abundance and annual fishing pressure when presenting assessment results and per recruit reference points. Reference abundance is the number of lobster 78+ mm CL on January 1 plus the number that will molt and recruit to the 78+ CL group during the year. The 78 mm CL size was chosen because it is lower end of the 78-82 mm size group in the assessment model which contains the lowest minimum legal size (81 mm) for lobster in all three stocks. Effective exploitation is the annual catch in number divided by the reference abundance.

Effective exploitation vs. full F

Effective exploitation and approximate full *F* estimates from basecase model runs had similar trends but full *F* was higher and more variable (Figure 6.2.1). The relationship between the two types of mortality estimates was not one to one because of variability in size selectivity caused by changes in regulations, size structure and inter-annual variability in recruitment (Figure 6.2.2). In contrast, the relationship between effective exploitation and full *F* was one-to-one in per recruit model runs (not shown) which assume constant size selectivity and recruitment.

History and relationships among models

The University of Maine model is similar to models used for lobster stocks in New Zealand (Breen et al. 2000) and for sea scallops off the northeastern US (NEFSC 2007). These approaches all belong to a larger class of models that use size-transition matrices to represent growth (Sullivan et al. 1990). Preliminary versions of the University of Maine model (Chen et al. 2005a) were presented and reviewed in previous lobster stock assessments (ASMFC 2004; 2006). Kanaiwa et al. (2008) evaluated performance of an earlier version of the model by simulation; however, its performance with simulated data probably exceeded the performance using real assessment data, which are complicated and often conflicting for lobster.

The University of Maine model is similar in biological assumptions and overall structure to recent versions of the "Life History" or "EPR" models used in previous lobster assessments for per recruit reference point calculations (ASMFC 2000). There are also similarities to the much simpler Collie-Sissenwine (1983) model (Section 6.1), which has been the primary assessment model in recent lobster stock assessments (ASMFC 2006). The main differences and similarities among models are:

1. Previous assessments (ASMFC 2006) used the CSM to estimate abundance and mortality rates. Prior to the 2006 ASMFC assessment, reference points from the Life History model. CSM is a very simple approach involving two size groups (new recruits and post-recruits), a single sex, landings data and data from a single survey (with adjustments to the survey data for growth). CSM is easy to apply and performs well in simulations (Mesnil 2003) but concerns were raised with using data from a single survey only, assumptions about survey selectivity (the "*q*-ratio"), and comparability of estimates to reference points calculated in

two different models that might not be comparable. In addition, mortality and abundance estimates from CSM are for the recruited stock and have become more difficult to interpret as legal minimum size limits have increased over time.

2. The University of Maine model postulates a single, well mixed stock. In reality, lobster stocks are spatially heterogeneous with spatial segregation by size and season and substantial spatial variability in mortality rates and abundance trends. Surveys are assumed to cover the entire stock area in the University of Maine model but, in reality, there are no surveys covering the entire GOM or SNE stock areas. The University of Maine model handles heterogeneity among surveys by generating different size-based selectivity curves. The previous approach using CSM was spatially explicit because separate CSM models were fit to the survey and landings data for each region with results combined to produce estimates for the whole stock.
3. The University of Maine and CS models simulate dynamics of an entire stock over time (including recruitments in each year and variability in mortality rates) while the Life History model simulates dynamics of a single cohort under equilibrium conditions (constant recruitment and mortality).
4. The University of Maine assessment model is fit by maximum likelihood to landings, surveys, and a wide variety other data; in contrast, the CSM model uses sums of squares to fit data from one survey only and the Life History model uses assumed parameters not estimated in the model.
5. It is possible to estimate variances and characterize statistical uncertainty in estimates from the University of Maine model (although efforts in this assessment to do so were not successful). CSM methods are well developed and it is easy to characterize statistical uncertainty although uncertainty due to differences among multiple surveys for a single area and uncertainty in landings data is generally ignored. The Life History model is not designed to estimate variances. It is possible to do so using simulation (Chen and Wilson 2002).
6. The structure of the University of Maine model is simpler than the Life History Model because fewer unique biological states are tracked. For example, ovigerous and non-ovigerous female lobster are not distinguished in the University of Maine model and lobster that have not molted for one, two or more years are not tracked separately.
7. The University of Maine model calculates spawning biomass per recruit but not egg production per recruit because effects of growth on molt frequency and spawning are not included. The Life History model calculates both spawning biomass and egg production per recruit, as well as yield and value per recruit and indicators of fishery efficiency under equilibrium conditions (constant recruitment and mortality).
8. In comparison to CSM, the University of Maine model allows analysts to make use of a wider range of information including multiple surveys simultaneously and commercial catch rates. It is not necessary to have length data for fisheries and surveys in all years. These advantages, however, make the University of Maine model more complicated and difficult to apply than the traditional CSM approach.

6.3 University of Maine model configuration

This section and table 6.3.1 summarizes the configuration of basecase models for each stock area. The text below provides additional details not available in the summary table or elsewhere in this report and particularly where there are differences among stocks.

Different model configurations were used in basecase models because: 1) data and circumstances differed among stock areas; 2) current code is limited to three surveys (although a single survey accommodates up to two sexes and four seasons); 3) best approaches to using the new assessment model are still being developed; and 4) different assessment team members worked on different stocks. Best available estimates of biological parameters were used in each basecase model.

Treatment of sexes by stock unit

Models for SNE and GOM tracked abundance of female and male lobster separately after recruitment and the sex ratio at recruitment was estimated in the model. All data for SNE and GOM were broken down by sex.

Although a wide range of configurations were explored, preliminary models for GBK with females and males separated were unsuccessful because trends in survey and landings data for male and females were not compatible (Figures 6.3.1 to 6.3.4). The apparent changes in survey and landings sex ratio could not be explained in the same model. As discussed in Section 7.3, these divergent trends in male and female data are a major uncertainty possibly related to management measures that protect females, trends in sex ratio of new recruits, or other factors. Trends in catches and survey data are more moderate in the combined sex data and changes in recruit sex ratio can be ignored. The basecase configuration for GBK in this assessment therefore combined females and males as a single sex.

Model years

Models for SNE and GOM covered 1982-2007. Models for GBK covered 1982-2008. The approach for GBK was intended to reduce variance of the estimates for 2007, which will be used to provide advice to managers. Only spring survey trend and length data from 2008 were available; therefore, SNE and GOM models which did not incorporate spring surveys did not cover 2008. Catch for GBK during 2008 was assumed equal to mean catch during 2003-2007. Model estimates for GBK during 2008 are not presented although diagnostic plots include spring 2008 survey data.

Landings and commercial size data

Landings data for GOM (Table 6.3.2) and SNE (Table 6.3.3)were numbers of lobster landed by year, quarter and sex. Landings data for GBK were the weight of lobster landed by year and quarter. Weight landed was used in place of numbers for GBK to minimize potential problems for years with low port- and sea-sampling rates. Landings in numbers for GBK are provided for reference (Table 6.3.4).

Commercial size data for SNE and GOM were available for all years and quarters. Commercial size data for GBK (sexes combined) were used only for years with adequate sampling (Table 6.3.5). In particular, commercial length data used in the model were for years and quarters with sampling from each of the combined statistical areas 521&526, 522&525, and 561&562. Statistical areas were grouped based on distance from shore (Figure 2.4.1) because sex ratio (proportion female) and size of GBK lobster generally increases as distance from shore increases.

Fishery-independent survey data selection

Differences between spring and fall trend and length composition data from bottom trawl surveys suggested seasonal differences in survey selectivity. These apparent differences in survey selectivity precluded treating spring and fall bottom trawl survey data from the same survey program as one survey (with the same survey selectivity). There were also differences in length composition between female and male lobster in the same survey during the same season. It would probably have been ideal to estimate selectivity curves for each survey, sex, and season but the structure of the current model precluded this comprehensive approach.

All available NEFSC fall and spring bottom trawl survey data were used for Georges Bank (no other surveys cover the GBK area). Some survey data were not used for SNE and GOM because there were more surveys available than could be accommodated in the model (i.e. three). A consistent approach was used to choose surveys for use in the GOM and SNE basecase models. Spring surveys were omitted because fall surveys tend to be less variable and are generally regarded as more reliable for lobster (it is hypothesized that spring surveys may be affected by temperature-dependent timing of spring migrations). Based on this approach, only NEFSC, MA DMF and ME DMR fall survey data were used for GOM. Similarly, only NEFSC, CT and RI fall survey data were used for SNE. NJ fall survey data were not used for SNE because trends for NJ were similar to that of the RI and CT fall surveys and length composition data were highly variable due to few years with adequate number of positive tows.

All data sources were weighted in the same fashion while fitting the model. In particular, standard deviations for goodness of fit calculations for survey trends were adjusted in preliminary runs to match the variance or residuals. Assumed sample sizes for length composition data were adjusted in preliminary runs to match effective sample sizes from goodness of fit.

Survey selectivity

Based on preliminary models and familiarity with the various survey programs, base case models for all three stock areas assumed that “offshore” NEFSC surveys had ascending logistic size selectivity curves. Large lobster tend to be found further offshore and in deeper water than small lobster due to ontogenetic changes in habitat use and heaviest fishing near shore. Under these circumstances, ascending selectivity curves seem reasonable. Low selectivity at relatively small sizes would probably occur due to escape of small individuals through meshes or under the rollers, use of rocky (difficult to sample) habitat by small lobster and limited spatial coverage of nearshore habitat by the NEFSC survey.

Based on preliminary models, familiarity with the various survey programs, and fishery effects, base case models for GOM assumed that “inshore” ME DMR and MA DMF surveys had a descending logistic selectivity curve. Selectivity curves for SNE, RI and CT bottom trawl surveys were dome shaped and skewed to the left with relatively long descending right hand sides. This type of dome shaped and descending logistic selectivity curves are reasonable for inshore surveys because the steep left hand side of the dome represents rapidly increasing selectivity due to increasing size. The descending right hand side of the selectivity curves is due to lack of coverage by inshore surveys of offshore habitat areas where large lobster are most common.

Commercial selectivity – conservation discards

The assessment model uses the proportion of female lobster caught that is discarded due to eggs or v-notches in calculating commercial size selectivity. The conservation component of commercial selectivity for all three stock areas was estimated using sea sample data in which ovigerous and v-notched lobster are counted and recorded. In particular, for a single size group, the ratio of female lobster without eggs and/or v-notches divided by the total number of female lobster is an estimate of the conservation component of commercial selectivity.

For GOM and SNE, proportions discarded due to eggs or v-notches were computed for all female lobster of the appropriate legal sizes in each year (e.g. all GOM female sea samples 81-127 mm in 1981 and 83-127 mm in 2000). Samples were then placed into 5 mm bins. Bins with less than 10 samples were eliminated. A weighted average of the proportion discarded in each bin was calculated by statistical area. Weights applied were the average landings in each statistical area over the assessment period. This approach was adopted to account for lack of balance in sampling effort, especially in SNE; a disproportionately large amount of offshore sampling effort occurs in statistical area 616, but most of the fishery effort is concentrated in inshore statistical areas 611 and 539 where the number of eggers is smaller. When all samples were treated equally, an unrealistically high proportion discarded was estimated for SNE than when statistical area 616 samples were down-weighted due to very few landings offshore.

Proportions discarded naturally declined at very large bin sizes due to poor sampling of larger animals, so these values were replaced with the maximum selectivity value observed. Finally, proportions discarded were subtracted from 1 to obtain conservation selectivity. In GOM, the same annual conservation selectivity per bin was used for all years due to lack of change in their long-term egger and v-notch program. In SNE, two different time periods of conservation selectivity were used: 1982-1999 and 2000-2007 due to the adoption of an intensive, short-term v-notch program by RI between 2000 and 2005 (see Appendix 2).

The assessment model for GBK modeled females and males as a single sex. Therefore, conservation selectivity was estimated after pooling sea sample data for female and male lobster. Sea sampling is limited on GBK for statistical areas other than 521, which is relatively near shore (Figure 2.4.1). Lobsters tend to be larger in these offshore area with more females. Under these circumstances, it was not possible to estimate separate conservation selectivity curves for individual years or quarters. Instead, only data from years and quarters with samples representing a broad cross-section of Georges Bank were used.

Proportions discarded in GBK due to eggs or v-notches were computed for lobster 78-152 mm using the 5 mm size bins used in the assessment model (Figure 6.3.5). The computed proportions showed clear trends, increasing linearly from 78 to about 110 mm and linearly decreasing at larger sizes. The proportions were smoothed using a hockey stick regression model. The complements (1-*p*) of the predicted proportions from the regression model (*p*) were used as the estimated conservation selectivity for sizes between 78 and 152 mm. Conservation selectivity at sizes < 78 mm is irrelevant because smaller lobster have never been landed. Conservation selectivity at sizes > 152 mm was assumed to be the same as at 148-152 mm CL.

Commercial selectivity – legal size, gear and other components

For all stock areas, legal size selectivity for a particular size group in each year was the catch-weighted average of legal size selectivity for sub-regions that had different minimum size regulations (Table 6.3.6). The legal size selectivity for a sub-region was the proportion of the size group that was legal size. For example, if a stock area was divided into sub-regions A and B with minimum legal size 81 and 82 mm CL, and landings were 10 and 20 mt, then the legal size selectivity for the 78-82 mm size group would be (83-81)/5=0.4 for sub-region A and (83-82)/5=0.2 for sub-region B. The legal size selectivity for the 78-82 mm size group in the entire stock would be (10*0.4+20*0.2)/30=0.27. Legal size selectivity was zero for smaller size groups and one for larger size groups. Legal size selectivity changed whenever legal size regulations changed. The initial legal size selectivity estimates were rescaled to a maximum value of one.

For all stock areas, gear selectivity was computed as the catch weighted average of gear selectivity for sub-regions that had different gear regulations. Gear selectivity for sub-regions was based on the minimum size of escape vents required in traps. Escape vent size was converted to selectivity estimates based on experimentally estimated proportions retained for gear with a range of escape vent sizes (ASMFC 2006 and Estrella and Glenn 2006). Gear selectivity changed whenever escape vent regulations changed. The initial gear selectivity estimates were rescaled to a maximum value of one.

For all stock areas, "other" selectivity due to other factors was assumed to be 1 for all size groups. Other selectivity was, in effect, turned off and not estimated because the additional parameters required (a mean and standard deviation for a lognormal curve) did not substantially improve fit and was difficult to estimate.

Growth transition matrices

Growth in lobster is complicated because it is discontinuous and depends on season, stock, size, gender, maturity, and on distributions of inter-molt duration (molting frequency) and molt increments, and because most of these factors are interrelated and unquantified. The growth transition matrices in the new assessment model estimate the net effect of all of these factors without assigning exact values. In contrast, the original Life History model separates calculations for the various processes affecting growth under assumptions of equilibrium. The assessment model used previously derived growth matrices without modification. The assessment model currently assumes that there is no inter-annual variability in growth rates. Growth is assumed to occur only at the beginning of the summer (major molt) and fall (molting period for second molters).

Sex-, season,- and stock specific growth transition matrices for the new model were calculated with an individual based simulation program used previously to test the assessment model (ASMFC 2006; Chen et al. 2005a). The individual based simulator is similar to the Life History model used for many years to calculate lobster reference points. To calculate "average" growth transition matrix, the simulations were run for a cohort of lobster (simulating equilibrium recruitment with constant natural and no fishing mortality). For each size bin, the average proportion of lobster not molting and proportions molting into a range of new size bins over the course of the cohort's life was recorded. The simulation used 1 mm size groups but average proportions were recorded for the 5 mm size bins used in the assessment model. The Life History model could have been used to carry out these simulations but the individual based simulator was more convenient.

Growth transition matrices in the new model specify the probability that a lobster will molt and the distribution of new size groups that it may reach for each season, sex and size group. This type of growth matrix has non-zero entries along the diagonal if there is any chance that a lobster of the corresponding size will not molt. In contrast, growth transition matrix calculated in the Life History model describes the distribution of new size groups that may be reached given that a lobster of particular size molts. This type of growth matrix always has zero entries along the diagonal. Thus, it was not possible to use standard Life History model growth information directly in the assessment model.

Based on Life History Model assumptions in the last assessment (ASMFC 2006), the maximum inter-molt duration assumed in growth matrix calculations was five years. Several steps were involved in using this information in the current assessment. The first step was to run the Life History Model with stock, sex, and size specific molt probabilities (e.g. the probability that a hypothetical female lobster 130 mm CL on GBK would molt 1, 2, 3, 4, or 5 years after the previous molt ASMFC (2006). The Life History Model generates an output file that describes the stock-, sex- and size specific probability of molting as a single "average" value (e.g. a hypothetical female lobster 130 mm on GBK has a 40% annual probability of molting, on average). Finally, the average molt probabilities for each size group were used in the University of Maine lobster simulator to calculate the growth transition matrix used in the new assessment model.

In so far as possible, assumptions in the simulations were the same as in the assessment model and previous applications of the Life History model. The simulations to calculate growth matrices used current best estimates of biological parameters including stock- and sex-specific molt increment distributions, and female maturity at length from ASMFC (2006). Natural mortality rates (instantaneous) for males and females were 0.1/4=0.025 per quarter when molting did not occur and 0.2/4=0.05 per quarter when molting occurred. Stock, sex, and size specific distributions for inter-molt duration in the simulation model were based on information provided by J. Idoine (NEFSC, pers. comm.).

Fishing mortality rates were assumed to be zero in simulations because of uncertainty about prevailing rates and fishery selectivity. Preliminary model runs with the simulator and Life History model showed that mortality did not affect “observed” growth (mean size of the cohort in each year) if the mortality was not size dependent. Thus, increases or decreases in natural mortality for all size groups would not affect observed growth. Observed growth with no fishing mortality was identical in the Life History, simulator, and assessment model, indicating that calculations were similar and probably correct in all three models. The simulations also showed that small differences in size dependent mortality (e.g. due to higher natural mortality when molting and decreases in molt frequency with size) had minor effects on observed growth. It is likely that size dependent mortality also affects observed growth by removing faster growing individuals also, but this phenomenon was not captured in simulations which did not include intrinsic growth variability among individual lobster.

Size dependent mortality and effects on observed growth might be expected in lobster because of substantial fishing mortality and fishery selectivity curves determined by minimum and maximum size limits. Observed growth would change under these circumstances because lobster at sizes fully selected by the fishery are removed at greater rates than lobster that are sizes not fully selected. Fortunately, calculated observed growth changed approximately as much in the assessment model as in the Life History model because size dependent mortality was accommodated in both cases. Thus, growth transition matrices from simulations under no fishing mortality suffice for growth calculations in the assessment model (Figure 6.3.6).

7.0 Results and Discussion

The University of Maine model was used as the primary analytical tool in this assessment. CSM model results (Section 7.1 below) and stoplight indicator analyses (Section 7.5) provide additional information and a means of building a bridge between the previous and new modeling approaches.

7.1 Collie-Sissenwine Model

A brief description of CSM results are presented for each of the three major stock assessment regions (GOM, GBK, and SNE) in terms of females and males combined and for females only and males only. Sex-specific results for GBK are generated directly from CSM runs (because there is one survey covering the entire area) whereas aggregate results for GOM and SNE are based on CSM results for different sexes and/or surveys (Section 6.1).

Although CSM estimates of scale for lobster are less certain than estimates of trend (ASMFC 2004), a number of practical results suggest that the scale estimates may be useful. Mortality estimates for males tend to be higher than for females in the same area. This pattern in model results is reasonable because management measures protect v-notched and ovigerous females. CSM mortality estimates are highest in coastal areas of SNE off Connecticut and Rhode Island. Relatively high mortality estimates are compatible with survey and fishery length composition data for these areas, which are truncated with few large lobster (inshore landings are mostly new recruits). Relatively high mortality estimates for coastal areas are also compatible with relatively high fishing intensity (fishing effort) near shore.

A variety of residual plots are presented in this assessment for CSM results but residual patterns do not necessarily indicate poor model performance. A review of individual runs from the simulation analyses conducted for the ASMFC model review (ASMFC 2004) showed that residual patterns (runs of positive or negative residuals) were common in CSM fits using simulated data with correlated measurement errors when the model was performing well based on mean squared error. Simulation analysis also showed serial changes in growth and natural mortality could reduce the reliability, accuracy, and precision of fishing mortality and abundance estimates.

7.1.1 Gulf of Maine results and discussion

Abundance and recruitment estimates for GOM are shown in Table 7.1.1.1, Figure 7.1.1.1, Appendix 3 Tables 1-4).Turn of the crank stock status measures were based on average abundance and fishing mortality during the most recent three years (2004-2006).

Trends in GOM as a whole and in the NEFSC survey area within GOM are very similar because abundance in the area surveyed by Massachusetts is low (Figures 7.1.1.2 and 7.1.1.3). NEFSC recruit indices and estimated recruit abundance for male and female lobster increased during 1982-2000 then generally declined thereafter. NEFSC post-recruit indices for male and female lobster increased from 1982 to the early 2000s then generally declined thereafter. Abundance estimates for male and female post-recruit lobster increased steadily during 1982-2003, but declined abruptly in 2003 and has continued to decline to the lowest point in the time series. Trends in estimated abundance of post-recruit females were similar to trends for males during 1982-1997; after 1997, female abundance increased more rapidly than male abundance. The proportion of the stock composed of recruits in GOM as a whole varied without trend and averaged about 60%.

Trends in the Massachusetts survey area within GOM were distinctly different from trends in the NEFSC survey area and in GOM as a whole (Figure 7.1.1.2 and Appendix Table 3). In particular, abundance has declined since 1999 for recruits, post-recruits and total lobster. This may be due to relatively high fishing mortality rates typical of lobster in coastal areas. Exploitation has been high but varied without trend from 1982 to 1998, averaging 80%, and has increased since to an average of 87% above the median since that time. Lobster in statistical area 514 were mostly new recruits ranging from 70% - 90% of the stock from 1982 to present. Landings (in numbers) increased from 1981 to 1990, remained high between 1991 and 2000, and have declined to a time series low in 2006. Landings, recruits, post-recruits, and the stock as a whole are roughly 50% female.

Landings (in numbers) in the Gulf of Maine were stable between 1981 and 1987, then increased steadily from 1988 to 1999, and have remained at record high levels since. Total annual exploitation rates declined steadily during 1982-2002, but increased abruptly in 2003 and are currently at the highest levels in the times series for both females and males. Landings, recruits, post-recruits, and the stock as a whole are roughly 50% female.

Residuals from recruit abundance indices for lobster in GOM (NEFSC and Massachusetts survey areas) had serial correlation (Figures 7.1.1.2 - 7.1.1.3). There was a tendency to under predict recruitment for female lobster in the Massachusetts survey area. In all areas of the GOM, CSM runs fit abundance data for post-recruits (which are relatively precise) better than abundance data for recruits.

7.1.2 Georges Bank results and discussion

NEFSC recruit indices for male and female lobster varied without trend during 1982-2000 then generally declined thereafter. NEFSC post-recruit index of females increased steadily throughout the time series whereas males decreased from 1982-1996, then increased through 2003, and declined sharply thereafter.

Abundance of male and female recruits and male post-recruits in GBK during 1982-2003 varied without trend (Table 7.1.2.1, Figure 7.1.2.1, Appendix 3 Table 5-6), and has declined to the time series average since. Female abundance has followed the same trend, while males have declined since 1998 and are currently below the time series average. Total abundance has followed the same pattern as females due to the high proportion of female in the stock (from 60% in 1982 to 82% currently). The proportion of the stock composed of recruits varied without trend and averaged about 40%.

GBK landings (in numbers) increased from 1.8 in 1982 to 2.3 in 1992. Since that point, landings have declined and leveled off at the time series average (1.8). Fishing mortality for the whole stock (sexes combined) varied without trend during 1982-1996 before declining through 2003. In recent years, mortality has increased to levels above the average of the time series. Male fishing mortality rates varied without trend from 1992 – 2003, and have increased to time series high levels at the present. Male mortality rates are consistently higher than those for females. Female fishing mortality rates varied without trend. Annual exploitation rates varied without trend during 1982-1996 before declining through 2003. In recent years, mortality has increased to levels above the average of the time series**.** Overall, females have comprised greater than 50-80% of the stock components and landings.

Residuals (Figure 7.1.2.2) from NEFSC survey recruit abundance indices for lobster in GBK had serial correlation. The CSM fit GBK abundance data for post-recruits (which are relatively precise) better than abundance data for recruits.

7.1.3 Southern New England results and discussion

All three (CT DEP, RI DEM, and NEFSC) recruit and post-recruit indices for male and female lobster increased during 1982-1997 then sharply declined thereafter. Abundance in SNE increased from 1982 until 1996 before declining to record lows by 2007 (Table 7.1.3.1, Figure 7.1.3.1, Appendix 3 Table 7-11). The decline of post-recruits began a year later (1997). Females have consistently represented an average of 60% the stock. Females contributed 60% of the total landings from 1982 – 1998 and that proportion has fallen to less than 50% in recent years. The proportion of the stock composed of recruits varied without trend and averaged about 70%.

Landings (in numbers) in SNE increased steadily from 1984 to 1996 before sharply declining to the present. Landings in 2006 were about 20% of the peak recorded in 1996. Fishing mortality for the whole stock (sexes combined) increased from 1984 to 1994-98 before declining to about the time series average thereafter. Male fishing mortality rates varied without trend but were higher than female fishing mortality rates. Annual exploitation rates (total landings over total abundance) varied without trend during 1982-1995 and declined slightly thereafter.

Residuals (Figures 7.1.3.2 -7.1.3.4) from recruit abundance indices for lobster in SNE had serial correlation. CSMs for SNE fit abundance data for post-recruits (which are relatively precise) better than abundance data for recruits.

7.2 University of Maine model

A single basecase model was developed for each stock area. In addition to the basecase, a range of alternative model runs and retrospective analyses were used to explore alternate hypotheses about lobster stock dynamics or data (Section 7.4).

7.2.1 GOM Basecase Results & Discussion

The basecase model fit increasing trends in the NEFSC fall survey but did not capture the downturn in relative abundance beginning in the mid-1990s (Figure 7.2.1.1). Fits to the largely trendless ME DMR fall survey were reasonable (Figure 7.2.1.2). Similar to NEFSC, fits to the MA DMF fall survey did not capture declines observed beginning in the early 1990s (Figure 7.2.1.3). Landings trends (in numbers) were fit well, although female and male fits were not exact in the summer season (Figure 7.2.1.4).

Commercial lengths were fit well by the model (Figures 7.2.1.5-6) but tended to exhibit negative residuals at intermediate lengths and positive residuals (observed > expected) at larger lengths (Figure 7.2.1.7). Length data from the NEFSC and ME DMR surveys were fit well with the exception of NEFSC data during 2002-2007 due to an increase in numbers of larger lobster observed (Figures 7.2.1.5-6 and Figure 7.2.1.8). The MA DMF survey lengths were the most variable of the three surveys and thus fits were good in some years and poor in others (Figures 7.2.1.5-6); model predictions tended to exhibit more positive residuals (observed > expected) at larger lengths since about 2000 (Figure 7.2.1.8).

Commercial selectivity curves were composed of gear, legal size, and conservation selectivity components only and were not estimated (Figure 7.2.1.9). Female lobster in GOM are roughly 12% mature at minimum legal size (~81-83 mm CL, Figure 7.2.1.10), indicating that the majority of female lobster recruit to the fishery before reaching sexual maturity. Estimated survey selectivity for NEFSC was an increasing logistic curve, whereas MA DMF curve was a decreasing logistic (Figure 7.2.1.11). Initial attempts to estimate survey selectivity for ME DMR also resulted in a decreasing logistic curve that fit length composition data well. However, model tuning diagnostics (GOF statistics) consistently indicated that selectivity of this survey should be a flat pattern, indicating all lobster within the range of lengths surveyed were equally selected. A flat selectivity pattern did not provide noticeably better fits to the length data, so the two parameters were fixed at the initially estimated values for a decreasing logistic selectivity curve.

Assumed log scale standard deviations for landings and survey data were similar to effective values in the basecase run (Table 7.2.1.1). Tuning of catch standard deviations was limited to a minimum of 0.05 and a maximum of 0.1. Assumed and effective sample sizes for commercial and survey length data were also similar (Table 7.2.1.2). Two exceptions were ME DMR and MA DMF females which showed unreasonably large effective values. When the model compared excellent female fits with poorer, sawtooth-like fits to smaller male lengths (Figures 7.2.1.5-6), it estimated extremely high effective samples sizes for females in both surveys. Misspecified growth of young males in GOM may be the reason for observed lack of fit of small males in survey length distributions.

Both estimated and observed annual landings in GOM more than doubled throughout the time period from about 14,000 mt in 1982 to about 32,000 mt in 2007 (Table 3.2.1.3 and Figure 7.2.1.4). Effective exploitation remained relatively constant across the time series at about 0.49 (Table 7.2.1.3 and 7.2.1.4 and Figure 7.2.1.12). Reference abundance increased to record levels by 2005 then declined slightly (Table 7.2.1.3 and 7.2.1.4 and Figure 7.2.1.12). Trends in spawning biomass decreased at the beginning of the time series, increased to a peak in 2005, and then decreased slightly (Table 7.2.1.3 and Figure 7.2.1.12). Recent increases in biomass and abundance were supported by increasing predicted recruitment throughout the time series (Table 7.2.1.3 and Figure 7.2.1.13).

Lack of fit to declining survey trends in recent years may be explained by the conflict between data sources used in the assessment. Observed length data and landings increased over time whereas relative abundance trends decreased. NEFSC survey length data and to a lesser extent commercial data both indicate an increase in abundance of large lobster in recent years that may be a response to record high recruitment. In contrast, the NEFSC and MADMF relative abundance trends have been declining for a decade or more. When all data sources are weighted equally, length information was favored. Attempts to place extra weight on survey trends forced better fits to relative abundance at the expense of fits to the landings with no large changes in fits to lengths. In addition, the model was challenged by the fact that no single survey data source represented the entire stock unit, yet the model assumes each survey is proportional to total abundance of the stock (see Section 7.3.1).

7.2.2 GBK Basecase Results & Discussion

The basecase model fit spring survey trend, spring survey length, fall survey length and commercial length data well but at the expense of the fall survey trend data which showed positive residuals (observed > expected) prior to 1995 and negative residuals after 2003 (Figures 7.2.2.1-3).

Commercial selectivity curves for GBK reflect the underlying assumptions about gear, legal size, and conservation selectivity components because none of the underlying components were estimated. Fishery selectivity curves for GBK (Figure 7.2.2.4) indicate that female lobster recruit to the fishery before reaching sexual maturity. Female lobster on GBK are 7% sexually mature at minimum legal size (Figure 7.2.2.5).

Estimated survey selectivity curves for NEFSC spring and fall surveys were similar (Figure 7.2.2.6). However, the spring survey had lower selectivity at large sizes to account for lower proportions of large lobster during spring.

Assumed log scale standard deviations and CVs for landings and survey data were similar to effective values in the basecase run (Table 7.2.2.1). Assumed and effective sample sizes for commercial and survey length data were also similar (Table 7.2.2.2). The assumed and effective values appeared generally reasonable.

The basecase model fit annual landings in weight data reasonably well (Figure 7.2.2.7). Trends in landings data were complicated (Figure 7.2.2.8). In particular, female landings peaked during 2006 while male landings peaked during 1993. In addition, the increase in female landed weight was faster than the corresponding increase in female landed numbers because average size of females in the catch increased substantially (Figure 7.2.2.9).

Effective exploitation declined steadily from 1982-2002 from about 0.45 to about 0.2 and then increased to about 0.28 during 2007 (Table 7.2.2.3, 7.2.2.4, and Figure 7.2.2.10). Reference abundance increased gradually during 1982-2002 and then increased quickly to record levels during 2004 (Table 7.2.2.3, 7.2.2.4, and Figure 7.2.2.11). Reference abundance declined rapidly after 2002-2007 (by about 33%) but was still at relatively high levels during 2007. Trends in spawning biomass (Table 7.2.2.3 and Figure 7.2.2.12) were similar although spawning biomass peaked slightly later during 2005.

Recent increases in effective abundance were apparently due to generally good recruitment after 1998 (Table 7.2.2.3 and Figure 7.2.2.13) and reduction in effective exploitation (Table 7.2.2.3 and Figure 7.2.2.10). Trends in effective exploitation (Figure 7.2.2.10) and fully recruit fishing mortality showed breaks in years when fishery selectivity changed due to changes in regulations. The basecase model predicts increases in abundance of large relatively old lobster (Figure 7.2.2.14) starting in about 2001 in response to consistently good recruitment during 1999-2004. This pattern is also evident in survey catch at length data (Figure 7.2.2.9) Recent declines in abundance and spawning biomass are due to a return to more typical recruitment patterns during 2005-2007.

7.2.3 SNE Basecase Results & Discussion

The basecase model fit overall survey trends well with two exceptions (Figure 7.2.3.1-7.2.3.3). First, the extreme peaks of all three surveys were not captured. Second, model fits to the CT DEP survey predicted an upturn (as seen in the NEFSC and RI DEM surveys) instead of additional decline as observed in the last four years (Figure 7.2.3.2). Landings trends (in numbers) were fit well, although summer fits and female fall fits were not exact (Figure 7.2.3.4).

Commercial lengths were fit well by the model (Figures 7.2.3.5-6 but tended to exhibit negative residuals (observed < expected) at intermediate lengths and more positive residuals (observed > expected) at small and large lengths since the late 1990s (Figure 7.2.3.7) Length fits for the CT DEP and RI DEM surveys produced similar residuals to commercial length fits (Figure 7.2.3.8). The NEFSC lengths fits were reasonable with the exception of positive residuals in the late 1980s-early 1990s and at larger sizes since 2000 (Figure 7.2.3.8).

Commercial selectivity curves were composed of gear, legal size, and conservation selectivity components only and were not estimated (Figure 7.2.3.9). In contrast to the other stock areas, female lobster in SNE are roughly 85% mature at minimum legal size (~81-83 mm CL, Figure 7.2.1.10), indicating that the majority of female lobster are sexually mature when they recruit to the fishery (Figure 7.2.3.10). Estimated survey selectivity for NEFSC was an increasing logistic, whereas the CT DEP and RI DEM curves were similar double logistic curves (Figure 7.2.3.11).

Assumed log scale standard deviations for landings and survey data were similar to effective values in the basecase run (Table 7.2.3.1). Tuning of catch standard deviations was limited to a minimum of 0.05 and a maximum of 0.1. Assumed and effective sample sizes for commercial and survey length data were also similar (Table 7.2.3.2).

Both estimated and observed annual landings (in numbers) in SNE increased fivefold from about 1,800 mt in 1982 to about 9,900 mt in 1997 (Table 3.2.1.3 and Figure 7.2.3.4). Effective exploitation remained relatively constant in the first decade, increased until 2002, then declined to historical lows thereafter (Table 7.2.3.3, 7.2.3.4, and Figure 7.2.3.12). Reference abundance increased steadily to record levels by 1997, declined precipitously, and then leveled off since 2004 (Table 7.2.3.3, 7.2.3.4, and Figure 7.2.3.12). Trends in spawning biomass followed a similar pattern to reference abundance (Table 7.2.3.3, 7.2.3.4, and Figure 7.2.3.12). Peak levels of biomass and abundance were supported by high predicted recruitment (Table 7.2.3.3 and Figure 7.2.3.13); recruitment declined to historical lows after 1999 and then increased slightly since 2004.

7.3 Uncertainty

It was not possible to characterize statistical uncertainty in results from the University of Maine model because asymptotic variances and likelihood confidence intervals were very small, implying unrealistically low levels of uncertainty. This was likely caused by specification (vs. estimation) of the growth transition matrix. Due to lack of time, it was not possible to use MCMC techniques to characterize uncertainty; therefore, the alternative model runs are the primary means for describing uncertainty in this assessment. See also Section 8.3.1 for a discussion of uncertainty in stock status determination.

7.3.1 Alternative model runs

A range of alternative University of Maine model runs were used to depict uncertainty in data and specified model parameters. Alternative runs are intended to depict uncertainty but are not intended as alternatives to the basecase model. Note that additional alternate models were run during retrospective analyses to explore reasons underlying causes of observed retrospective patterns.

GOM model

Five alternate model runs were carried out for GOM to address hypotheses and characterize uncertainty about survey and landings data (Table 7.2.1.4). Across the range of alternative models, recent effective exploitation ranged from 22% below the basecase to 7% above; reference abundance ranged from 30% below the basecase to 55% above.

The "Alternate catch at length (CAL)" run replaced the basecase landings trends and lengths with an alternate dataset that had been adjusted upward during 1997-2003 to correct for possible underreporting in NMFS dealer databases (Appendix 1). The total unweighted negative log likelihood for this scenario improved (-0.9 likelihood units) and modest changes in recent reference abundance were observed. Very little change (<3%) in recent effective exploitation, abundance, and spawning stock biomass was observed.

The "Track fall survey trends" run included the two GOM surveys with recent downward trends in relative abundance, namely the NEFSC fall survey and the MA DMF fall survey. The NEFSC survey was split such that males and females were split and treated as different datasets and the MA DMF survey remained as one dataset with sexes combined. In addition, a heavy weight was placed on the fall trend likelihood component. This run was an attempt to generate a worst-case-scenario that would estimate the most conservative lower bound on current stock status given the available data. This model has the highest total negative log likelihood value and did not fit the data well compared with other models. As expected, it did produce the highest estimate of female effective exploitation, and reference abundance and spawning stock biomass estimates that were about 30% lower than the basecase.

The “Track fall survey trends with alternate catch-at-length” run was the same as the previous alternate run except the basecase landings dataset was replaced with the alternate (Appendix 1). This model has a high negative log likelihood and did not fit the data well. However, the highest estimate of effective exploitation on males and combined sexes (about 7% higher than basecase) was generated by this model run.

The “Track spring trends” run included the NEFSC spring survey (sexes split into different datasets) and the ME DMR survey (sexes combined in same dataset). A heavy weight was placed on the spring trends. This run was an attempt to generate a best-case-scenario that would provide a potential upper bound estimate of current stock status given the available data. However, this alternate model run provided the poorest fit of all. Estimated reference abundance and spawning stock biomass were about 55% higher than the basecase, whereas estimated exploitation rates were lower about 22% lower.

The “Spring & fall trends” run included the NEFSC fall and spring surveys and the ME DMF fall survey. Overall, this model produced the lowest total negative log likelihood, driven mainly by superior statistical fits to the ME DMR male lengths. However, this model did not differ much visually in fits to observed data, and stock status measures were almost identical to the basecase (<2% difference).

GBK model

Seven alternate runs addressing key uncertainties and hypotheses were carried out for GBK, in addition to the basecase run (Table 7.2.2.4). Key model estimates were moderately sensitive to differences among model runs. Recent reference abundance and effective exploitation levels ranged from about -16% to +14% of estimates from the base case model.

The “Male growth” run substituted the GBK male growth matrix in place of the average female plus male growth matrix used in the basecase run. Male growth is faster than female growth and the scenario was used to examine the hypothesis that lobster growth rates on GBK may be underestimated. The total unweighted negative log likelihood for the scenario improved substantially (-62.5 likelihood units) in the Male growth scenario. Changes to recent reference abundance and effective exploitation were modest.

Two alternate runs with M=0.1 and 0.2 y^{-1} (M=0.15 in the basecase run) indicate that assumptions about natural mortality (M) over this narrow range had little effect on model fit or stock estimates.

The “Fit survey trends” and “Fit survey lengths” runs indicate that survey trend and survey length data provide conflicting information. Survey length data appear to favor relatively high abundance estimates while survey trend data favor lower abundance estimates. The Fit survey trend run used low weights on survey length data. In this run, fit to survey trend data increased modestly, fit to commercial length data improved substantially and fit to survey length data was relatively poor. The “Fit survey lengths” scenario used low weights on survey trend data. The Fit survey trend run had the poorest fit overall based on total unweighted negative log likelihood and highest effective exploitation estimate in the set. In contrast, the Fit survey lengths run had a total negative log likelihood that was about the same as the basecase and the lowest effective exploitation estimate in the set.

Differences in recent trends between the spring and fall surveys are the most obvious conflicting signal in assessment data for GBK. To understand the significance of the differences in recent trends and to better understand relationships between fit to survey trend and length data, the “Fit fall survey” run used low weights on the spring survey trend and length data while the “Fit spring survey” run used low weights on the fall survey trend and length data. In the Fit fall survey run, goodness of fit was similar to the basecase for most components with the exception of the spring survey length data which had a substantially poorer fit. In the fit spring survey run, overall goodness of fit was similar to the basecase except that fit to the spring survey lengths was much better and fit to the fall survey lengths was much worse. Recent effective exploitation was relatively high in the fit fall survey run and relatively low in the fit spring survey run, as might be expected based on the recent decreasing trend in the fall survey and recent increases in the spring survey.

SNE model

Two alternate runs addressing key uncertainties and hypotheses about the assumed value of natural mortality were carried out for SNE in addition to the basecase run. Across the range of alternative models, recent reference abundance increased 7-10% and effective exploitation levels decreased up to 20% from the basecase model.

All models (basecase and alternative) began with an M = 0.15 during 1982-1997. The first alternative model differed from the basecase only in that the assumed value of M increased by 50% to an annual value of 0.225 for the years 1998-2007. The second alternative model doubled the value of M to 0.3 during the years 1998-2007.

The first alternative model (M in later years = 0.225) was the best fit (exhibited the lowest total negative log likelihood) of all three models, indicating that an increasing trend in M allowed the model to better fit the data provided (Table 7.2.3.4). With the exception of the NEFSC female trends and NEFSC male lengths and landings, most likelihood components exhibited lower negative log likelihood values in one of the two alternative models (those with increasing trends in M). In general, higher values of M provided better fits to the CT DEP survey trends and lengths components of the model; one potential explanation for this result may be that the area of Long Island Sound represented by the CT DEP survey experienced higher levels of natural mortality than RI or offshore waters.

7.4 Retrospective pattern analyses

Retrospective pattern analyses were used to evaluate both the CSM and the University of Maine model. For the latter, retrospective pattern in several alternate runs was examined as well. Starting with the basecase run, one year of data was dropped for each run up to a maximum of 6 years. The resulting reference abundance and effective exploitation estimates were compared graphically and numerically to basecase estimates using Mohn’s rho (1999)(Table 7.4.1.1):

$$\rho = \sum_{y=2001}^{2006} \frac{\left(X_{y,y} - X_{y,2007}\right)}{X_{y,2007}}$$

where $X_{y,x}$ is the estimate of effective exploitation or reference abundance for year y from the run with terminal year x.

7.4.1CSM

Retrospective plots and Mohn's rho statistic were used to evaluate retrospective patterns for CSM runs for each sex and survey. This CSM is not designed to use multiple surveys simultaneously, so retrospective analyses of combined sexes and/or stock components were not possible. Abundance of recruits, post-recruits, and exploitation rate estimates were examined. Runs were made by sequentially removing the terminal year from 2007 back to 2001. In general, recruit estimates exhibited the most notable patterns.

For the GOM runs based on the MA_DMF survey (statistical area 514), recruits for females and males showed some pattern due to uncertainty in the terminal estimates such that recruit abundance was usually underestimated (Figure 7.4.1.1). Post recruits for both sexes showed no problems, possibly due to low abundance in recent years. Exploitation also exhibited no problems in the patterns, though the values have been high (> 80%) since 1982. The GOM NEFSC runs showed little pattern for either sex in abundance or exploitation (Figure 7.4.1.2). In all cases, terminal year uncertainty tends to increase the entire time series of abundance estimates and decrease the entire series of exploitation estimates.

For the GBK runs (Figure 7.4.1.3) recruits for females and males showed little pattern for either sex in abundance or exploitation. In all cases, terminal year uncertainty tends to increase the entire time series of abundance estimates and decrease the entire series of exploitation estimates.

For the SNE runs based on the CT survey (Figure 7.4.1.4), recruits for females showed little pattern due to uncertainty in the terminal estimates. However, the 2006 survey index value of 0 for male post-recruits made estimates unrealistic; the effective exploitation plot in figure 7.4.1.4 omits the 2005 point estimate (*mu* > 2.0). Post recruits for females showed no problems, possibly due to low abundance in recent years. As in the case for male recruits, the 2005 terminal year run for male post-recruits showed little pattern other than 2005. Exploitation for both sexes (except for males in the 2005 run) also exhibited little pattern, though the values have been high (80 - 95%) since 1982. For the SNE runs based on the RI survey (Figure 7.4.1.5), terminal estimates of recruit abundance for females tended to be overestimated. Post recruits for both sexes showed little pattern with the exception of 2002 (females) and 2003 (males). Exploitation for females was typically underestimated, though the values have been high (70 - 90%) since 1982. Again, the 2003 terminal year run for males showed similar problems to that seen in abundance estimates. For the SNE runs based on the NEFSC survey (Figure 7.4.1.6), little pattern was shown for abundance and exploitation. With the exception of the 2001 terminal year run, the model tended to increase the entire time series of abundance estimates and decrease the entire series of exploitation estimates.

7.4.2 GOM model

The GOM basecase and an additional six alternate models were analyzed for retrospective pattern. Runs began with a terminal year of 2007 and ended with a terminal year of 2001 with the exception of the basecase, "Alternate CAL", and "Remove ME DMR" models which were analyzed back to 1998 (two years prior to start of the ME DMR survey). However, all Mohn's rho statistics were calculated using the years 2007-2001 for comparison.

The basecase model exhibited retrospective bias that underestimated abundance and overestimated exploitation rate across the time period examined (Figure 7.4.2.1). Bias became progressively worse as the number of years of data in the ME DMR survey decreased (2007-2000), but terminal year estimates improved after no ME DMR data remained in the analysis (1999-1998). Overall magnitude of retrospective pattern was moderate (Table 7.4.2.1). However, removing the ME DMR survey altogether worsened retrospective bias, indicating that the ME DMR survey may be providing information that helps the model balance conflicting trends in the two declining surveys (MA DMF & NEFSC) and increasing length structure (commercial and survey).

To explore more deeply the hypothesis of conflicting trends in survey data sources, retrospective analyses of two new model runs were explored. The "Offshore surveys only" run included just the NEFSC fall survey and the "Inshore surveys only" included just the fall inshore surveys (ME DMR and MA DMF). The "Offshore surveys only" run greatly reduced retrospective pattern to levels on par with the "Alternate CAL" run likely because similarities between commercial and NMFS length data provided little conflict. In contrast, the "Inshore surveys only" run increased retrospective pattern above that of the basecase (Table 7.4.2.1). Therefore, basecase model results likely represent a balance between conflicting trends among inshore and offshore indices.

Note that neither the "Offshore surveys only" run nor the "NEFSC and MA DMF only" run produced declining population estimates similar to CSM results (Figure 7.1.1.3). This may be because the CSM is a two-stage model (length-based recruit and post-recruit classes) and thus relies heavily on survey trend information to predict population trends. If large lobsters do not contribute substantially to stock dynamics, then CSM results which closely track survey trends in relative abundance will be more representative of GOM stock dynamics. In contrast, the University of Maine model tracks abundance of all lobsters >53mm as they grow and survive to larger length classes; assuming large lobsters serve as an important source of recruitment for the stock, the University of Maine model will likely not predict population declines as seen in the CSM as long as the length structure of the surveys and catch continues to expand.

Replacing the basecase landings data with the alternate landings dataset (Appendix 1) nearly halved the magnitude of retrospective pattern (Table 7.4.2.1). This result, in combination with the fact that this model exhibited the lowest/best negative log likelihood among alternate models, indicates that the alternate landings data may provide a reliable correction to basecase data.

Two very different models were constructed to explore the concern that surveys available for use in this assessment do not reflect dynamics of the entire stock unit. The first was an "Area 3" model configuration that represented the offshore lobster portion of the GOM stock unit (Figure 2.4.1) and included only landings from offshore statistical areas and the NEFSC fall survey. The second was an "Area 514" model configuration that included only statistical area 514 (Figure 2.4.1) landings and the MA DMF fall survey. The "Area 514" model converged and exhibited almost no retrospective pattern (Table 7.4.2.1), indicating the landings and survey data were likely well paired. Given the small area of coverage, this model may have performed well because it was not challenged with conflicting data sources or surveys that did not represent total stock abundance. In contrast, the “Area 3” model which covered a much wider area and included more variable length data was unstable, did not converge, and exhibited extreme retrospective bias.

7.4.3 GBK model

Retrospective plots and Mohn’s rho statistic were used to evaluate retrospective patterns in the basecase and Fit spring survey runs for GBK lobster (Table 7.4.2.1). The Fit spring survey run with low weight (λ=0.0001) on fall survey trend and length data was of interest because conflicting trends in the fall and spring surveys might affect retrospective patterns. Starting with the basecase run, one year of data was dropped for each run. The resulting reference abundance and effective exploitation estimates were compared graphically and numerically to basecase estimates using Mohn’s rho.

The details of retrospective analyses for GBK were somewhat different than for other stocks but results are directly comparable. In particular, the basecase model for GBK included spring survey data for 2008 (with mean catch during 2003-2007 assumed for 2008) to obtain a terminal estimate for 2007. Similarly, the first retrospective run for GBK used data through the spring survey in 2007 to obtain a terminal estimate for 2006 and so on. The last step in the retrospective analysis was a run with data through the spring survey in 2002 to obtain a terminal estimate in 2001. The true catch in the last year was used in each retro run, in place of the average catch during the previous five years.

Results for GBK indicate little or no retrospective bias with the basecase (Figure 7.4.2.2) or Fit spring run (Figure 7.4.2.3) because differences between the basecase and retrospective run estimates were both positive and negative. The absolute value Mohn’s rho indicated moderate retrospective pattern. Retrospective analyses point out effects of conflicting trends in the spring and fall survey. In particular, the scale of estimates from the basecase run changed substantially after one year of data was omitted. In contrast, the run which emphasized the spring survey gave similar estimates in each retrospective iteration.

7.4.4 SNE

The SNE basecase and two alternate models were analyzed for retrospective pattern. Runs began with a terminal year of 2007 and ended with a terminal year of 2001. The basecase model produced moderate retrospective pattern (Table 7.4.2.1) that was slightly biased such that effective exploitation was underestimated and reference abundance was overestimated (Figure 7.4.2.4).

The “Trend in M” run was a retrospective analysis of the second alternative model in which the value of M doubled to 0.3 during the years 1998-2007. Retrospective pattern more than halved with incorporation of a trend in M. This result, in combination with the fact that the “Trend in M - up 50%” model exhibited the lowest/best negative log likelihood among alternate models, indicates that an increasing trend in M is supported by the data and should be explored further in future assessments.

One new model was constructed to explore the concern that surveys available for use in this assessment do not reflect dynamics of the entire stock unit. The “Area 611” model represented the inshore Long Island Sound portion of the SNE stock unit (Figure 2.4.1) and included only landings from statistical area 611 and the CT DEP fall survey. Despite the close pairing of landings and survey data in this model run, the model did not reliably converge. However, this model did exhibit levels of retrospective pattern intermediate to the basecase and “Trend in M” runs.

7.4.5 Summary of concerns about spatial coverage of surveys used in modeling

The application of the University of Maine model in GOM was challenged by the use of multiple, regional, fishery independent surveys that exhibited conflicting trends. Three surveys were used in the GOM basecase: 1) the ME DMR survey which represents the upper to middle portion of inshore GOM, 2) the MA DMF survey which represents the southern portion of inshore GOM, and 3) the NEFSC survey represents the offshore portion of GOM. Relative abundance of each GOM survey may adequately represent regional population trends, but no single data source represents conditions across the entire stock unit. This poses a problem when surveys exhibit different trends in relative abundance over time because the model assumes each survey is proportional to total stock abundance. The model therefore attempted to find a balance among all three data sources when finding the best fit to the data provided; as a result, it did not fit any single survey trend well. In contrast, the SNE basecase also used three different regional surveys, but overall trends in relative abundance were quite similar so the model did not have a problem finding a solution that fit all the surveys well. To help characterize some of the uncertainty arising from this problem, several alternative runs (Section 7.3.1) and retrospective analyses were performed (Sections 7.4.2 & 7.4.4). These alternative runs were used to help evaluate the consequences of using one data source versus another (the potential “extremes” of stock conditions).

One advantage of the lobster CSM versus the University of Maine model is that it is more spatially explicit in that it matches regional catch with survey data. However, the CSM assumes that the surveys provided cover all important areas of the stock and that their additive results represent total stock abundance; these assumptions could be problematic in GOM given the MA DMF and NEFSC surveys used do not represent the area where most of the fishery occurs (inshore GOM).

Ideally, a single stockwide survey would be conducted in each stock unit (especially GOM) and used to characterize total stock dynamics. In the absence of such a program, a spatially explicit version of the University of Maine model could help resolve these issues, however the data needed to parameterize such a model are not currently available. Specifically, stock units would need to be very well defined and detailed information about regional contributions to stock productivity and size-and sex-specific migration among regions within a stock would be necessary.

7.5 Stock indicators

In addition to standard model based fishing mortality and abundance estimates, a number of empirical stock indicators were examined to judge stock status. These stock indicators provide information about the overall health of each stock independent of assessment models. Three categories of indicators were generated: mortality, abundance, and fishery performance. With the exception of sex ratio, the annual value of each stock indicator time series was categorized as positive, neutral, or negative based on its quartile ranking (details below). Fishery performance indicators were classified in the same manner as abundance indicators, with the exception of the number of traps fished and set over days, which were classified like a mortality indicator. Similar to the proposed reference points this method allows for a relative comparison of stock status. For all indicators, the terminal three year average (2005-2007) will be used to assess the status.

7.5.1.1 Mortality Indicators

We provide the following indicators of mortality: exploitation rate (*u*), median length in survey, and recruits as a percentage of exploitable stock. Most mortality indicators were classified as follows; annual values that were less than the 25th percentile were classified as "positive", annual values between the 25th and 75th percentile were classified as "neutral", and annual values that were greater than the 75th percentile were classified as "negative". One exception was median length >77 mm which was classified as positive when annual values were greater than the 75th percentile and "negative" annual values were less than the 25th percentile. Stock indicators by year are characterized by location in quartile in the time series distribution.

	≤ 25th quartile	Between 2nd and 3rd quartile	≥ 4th quartile
1. Exploitation rate (*u*)	Positive	Neutral	Negative
2. Median length > 77 mm	Negative	Neutral	Positive
3. Recruits as % of exploitable stock	Positive	Neutral	Negative

The rate of exploitation is the landings in number divided by the reference population (> 77 mm) for each survey. A separate value was calculated for each survey by assigning the appropriate landings based on statistical area(s) covered by the survey (Table 2.4.1). Median length greater than 77mm in each survey catch was selected as representative of the size structure of harvestable lobster for that year. This metric is an indicator of mortality as higher mortality rates should result in lower median lengths. However, the median length is also influenced by the strength of recruitment, and a strong recruitment may also lower median length.

Recruits as a percentage of exploitable stock is also used as an indicator of mortality for this reason. Recruits were defined as 10 mm below legal minimum size for each survey. The exploitable stock is defined as all lobster larger than minimum legal size. Higher percentages of recruits in the population are consistent with higher total mortality rates. However, the percent recruits are also influenced by strength of recruitment: a strong pulse of recruitment will increase the percentage of recruits. In all three stocks indices of recruits and full recruits (legal size) lobster have been correlated over the time series because the age classes blur together as they reach maturity. Disruption of the long term relationship between size classes would indicate a negative growth pattern and/or declining size structure. Recruits as a percentage of total population also indicates the dependency of the fishery on recruitment.

7.5.1.2 Abundance Indicators

Six indicators were generated to assess relative abundance, total spawning potential, and year class strength of each stock. These indicators include: spawning stock index, recruit abundance, full-recruit abundance, sex ratio of recruits and full-recruits (legal size) and a recruitment index of larval production or young-of-year (YOY) settlement. Abundance indicators were classified as follows; annual values that were less than the 25^{th} percentile were classified as "negative", annual values between the 25^{th} and 75^{th} percentile were classified as "neutral", and annual values that were greater than the 75^{th} percentile were classified as "positive". The exception for this was the sex ratio which was classified as the proportion female with less than 0.1 and greater 0.9 was negative; greater than 0.1 and less than 0.4 and greater than 0.6 and less than 0.9 was neutral; and greater than 0.4 but less than 0.6 was positive.

<table>
<tr><th></th><th colspan="2">≤ 25^{th} quartile</th><th>Between 2^{nd} and 3^{rd} quartile</th><th colspan="2">≥4^{th} quartile</th></tr>
<tr><td>4. Spawning Stock Abundance</td><td colspan="2">Negative</td><td>Neutral</td><td colspan="2">Positive</td></tr>
<tr><td>5. Full Recruit Abundance</td><td colspan="2">Negative</td><td>Neutral</td><td colspan="2">Positive</td></tr>
<tr><td>6. Recruit Abundance</td><td colspan="2">Negative</td><td>Neutral</td><td colspan="2">Positive</td></tr>
<tr><td>7. Sex Ratio (Full Recruits)
8. Sex Ratio (Recruits)</td><td>≤ 0.1
Negative</td><td>>0.1 to ≤ 0.4
Neutral</td><td>>0.4 to <0.6
Positive</td><td>≥0.6 to <0.9
Neutral</td><td>≥ 0.9
Negative</td></tr>
<tr><td>9. Recruitment Indices</td><td colspan="2">Negative</td><td>Neutral</td><td colspan="2">Positive</td></tr>
</table>

The spawning stock abundance index reflects the reproductive potential of the stock in a given year for each survey. It is calculated as the cumulative sum of the product of number per tow, mean weight at size and maturity at size for each one mm increment with yearly totals scaled to the maximum value of the time series.

$$SSI = \sum_{CL \to \infty} (NumPerTow * Weight * Maturity)$$

The full recruit abundance is the combined number per tow of lobster (sexes combined) greater than the minimum legal size. The recruit abundance is the combined number per tow of lobster 10 mm less than minimum legal size. The recruit abundance is intended to represent an approximation of the number of lobster that might be expected to molt into the fishery within one year of the survey.

The sex ratio of lobster in surveys was investigated as an abundance indicator. The sex ratio of fully recruited (legal size) and recruit lobster is the ratio of the number of females to the total number (sexes combined) in each survey. A skewed sex ratio towards female or male lobster may indicate reproductive limitations in the population. For sex ratio indicators, we depart from the standardize quartile ranking and use a ratio scale. A sex ratio ≤ 0.1 and ≥ 0.9 is considered a negative indicator. Sex ratios >0.1 and ≤ 0.4 or ≥ 0.6 and < 0.9 are considered to be neutral. Finally, sex ratios >0.4 and <0.6 are considered to be a positive indicator of a stable population.

Recruitment indices are an annual estimate of the median density of late-stage (fourth instar) larvae or young- of year (YOY) or post larvae for each stock. Sustained high levels of larval or post larval density would indicate favorable production. Annual densities of YOY lobster in the Gulf of Maine are represented with permission from Beaver Harbor (statistical area 468), New Brunswick (Lawton et. al. 2001), ME DMR, MA DMF and the Bigelow Laboratory for Ocean

Sciences. Data describing annual densities of late-stage larval lobster at seven sites in western Long Island Sound are provided by the CT DEP Larval Survey (Giannini 2008) and entrainment estimates at the Millstone Nuclear Power Station in eastern Long Island Sound (DNC 2008). The only annual index of YOY in SNE was provided by RI DMF. There are no recruitment indicators for GBK.

7.5.1.3 Fisheries Performance Indicators

Eight indicators were used to describe the performance of the fishery in each stock area during the 1981 through 2007 assessment period: effort, landings, median length of the catch, gross CPUE, price per pound, gross stock revenue and revenue per trap. Fishery performance indicators were classified in the same manner as abundance indicators, with the exception that the number of traps fished and set over days were classified like a mortality indicator. For indicators where the price per pound was used, an additional adjustment was computed to account for inflation based on the unprocessed fish consumer price index with 2007 as the base year (www.bls.gov).

	≤ 25th quartile	Between 2nd and 3rd quartile	≥4th quartile
10. Effort (number of traps)	Positive	Neutral	Negative
11. Landings (pounds)	Negative	Neutral	Positive
12. Median Length	Negative	Neutral	Positive
13. Gross CPUE (Pounds/Traps)	Negative	Neutral	Positive
14. Set over Days	Positive	Neutral	Negative
15. Price Per Pound	Negative	Neutral	Positive
16. Revenue	Negative	Neutral	Positive
17 Revenue per Trap	Negative	Neutral	Positive

The number of traps in each stock area was used as an indicator of effort. The number of traps does not account for how many traps were actually deployed in the fishery, the average set-over-days or changes in gear efficiency/design. An accurate accounting of total trap numbers for Georges Bank was unavailable, therefore annual numbers of traps fished on Georges Bank by Massachusetts lobstermen were used as a proxy for the entire stock area. Trap numbers in RI were omitted from the indicator assessment because of their inconsistent time series.

Landings were assigned to each stock area and represent a common indicator of fishery performance. For the Gulf of Maine, the alternate catch at length matrix was not used. The annual median length of landed lobster was generated for each stock area, based on expansion of sea sampling measurements to total landings. Unidentified landings by location, and possible underreporting, can introduce error into these estimates. For each stock, the catch- at- length matrix (Section 5.1.3) was used to determine median length. Pounds landed divided by the number of traps fished was used as a gross measure of CPUE.

When available, the annual average soak time of traps was used as an additional indicator of fishery performance by stock area. Regulations limiting trap numbers would be expected to force fishermen to fish more efficiently and at a higher frequency (shorter set time). In the Gulf of Maine, soak time information was available from Maine and Massachusetts. On Georges Bank, information was available from Massachusetts only. In Southern New England, information was available from Massachusetts, Rhode Island, and Connecticut.

The average ex-vessel price was queried to provide an estimate of value to the fishermen for each pound of lobster landed (personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD). In areas where the total catch has changed significantly over the assessment period average price per pound was an indicator of price elasticity. To assess how ex-vessel price has changed relative to inflation, price per pound was adjusted to 2007 US dollars using the unprocessed fish consumer price index (www.bls.gov).

Gross revenue to the fishery was estimated as the product of average price per pound and landings (raw and adjusted). Finally, the average revenue per trap was estimated using the number of traps and total revenue for each stock and year.

7.5.2 Stock Indicator Results

In general the stock indicators need to be interpreted cautiously due to the short time series available for analysis. The most recent 25 years of stock indicators may not be reflective of the entire productive range of the stock. The strengths of this approach are that the use of quartiles is objective and the focus on trends is straight forward without regard to modeling assumptions.

7.5.2.1 Gulf of Maine

Mortality indicators for the terminal years (2005-2007) are mostly neutral (Table 7.5.2.1.1). One exception was the NEFSC Fall Survey exploitation rate which was negative (above 75th quartile). Two positive exceptions were the NEFSC Fall Survey median length (above 75th quartile) and proportion of the exploitable stock comprised of recruit indicators (below 25th quartile).

Abundance indicators for recent years are mostly positive or neutral (Table 7.5.2.1.2). Spawning stock abundance index results are positive or neutral for all surveys in the terminal years. Full recruit and recruit abundance are positive or neutral for all surveys with the exceptions of the Massachusetts Fall Survey which is negative.

Sex ratio for full recruits is neutral or positive for all surveys. Sex ratios for recruits are positive with the exception of the Maine Spring Survey which is neutral. Terminal year recruitment indices are positive (above the 75th quartile) for all areas with the exception of Mid-Coast Maine survey which is neutral.

The fishery performance indicators have been largely positive for recent years (Table 7.5.2.1.3). Average landings, median length, pounds per trap, revenue, and revenue per trap are all positive (above the 75th quartile). Exceptions to this trend are the number of traps and average soak time of traps fished, which are negative (above the 75th quartile). The average price per pound is positive while the adjusted price per pound is neutral.

7.5.2.2 Georges Bank

The status of the Georges Bank stock and the fishery have been relatively stable until recent years. The mortality indicators for the recent years (2005-2007) are all positive or neutral (Table

7.5.2.2.1). Exploitation rate is neutral for both Fall and Spring NEFSC Surveys. The median length and percent of the exploitable stock comprised of recruits fall is positive (above the 75th quartile) during this period.

Abundance indicators for the recent years (2005 to 2007) are mixed from generally positive to neutral with one negative indicator (Table 7.5.2.2.2). The spawning stock abundance index and full recruit abundance were positive for the Fall and Spring NEFSC Survey. The recruit survey abundance (lobster 10 mm below minimum legal size) was neutral in the spring survey and negative in the fall survey. The sex ratios for full recruits are neutral (between 60 and 90% female), while the sex ratios for recruits are positive (between 40 and 60%).

Fishery performance indicators for recent years are mixed but generally positive (Table 7.5.2.2.3). Estimates of traps in the terminal years are neutral (falling between the 25th and 75th quartile) but are solely based on Massachusetts levels that may not reflect levels of effort across the entire GBK stock area. Commercial catch, median length and gross pounds per trap are positive. Average soak time of traps has increased over the time series and is a negative indicator. Price per pound, revenue, and revenue per trap are all positive with the exception of adjusted price per pound which was neutral.

7.5.2.3 Southern New England

Mortality indicators are mixed in SNE. In SNE offshore waters covered by NEFSC Fall and Spring Surveys and in Rhode Island waters, exploitation has been neutral or positive for the period of 2005 to 2007 (Table 7.5.2.3.1). However, exploitation for Long Island Sound (area 611, CT Survey) and the inshore waters of NJ are negative, with the exception of the NJ Fall Survey which is neutral. Median lengths are positive or neutral for all surveys during 2005 to 2007. The percent of the exploitable stock comprised of recruits was negative or neutral with the exception of the Fall NEFSC Survey which was positive. These three survey areas were fishing under differing minimum gauge sizes which may have contributed to the resulting inconsistent trends.

Abundance indicators for SNE are generally negative or neutral (Table 7.5.2.3.2). Spawning stock abundance was neutral for the average of 2005 to 2007 for NEFSC and RI Surveys but negative for CT Fall and Spring Surveys. Full recruit (legal) abundance was negative to neutral with the exception of RI Fall Survey which was positive. Recruit indices were neutral to negative in the terminal years for all indices. Average sex ratios for 2005-2007 were positive (between 40-60% female) for all data except for the RI fall survey recruits which were neutral (37%). The 2005-2007 averages for the three larval and young-of-year indices of recruitment were neutral.

The fishery performance indicators are generally negative for the 2005 to 2007 average (Table 7.5.2.3.3). Commercial catch, pounds per trap, average soak time, adjusted revenue and adjusted revenue per trap are all negative in the terminal years 2005 to 2007. The price per pound, un-adjusted revenue and un-adjusted revenue per trap were neutral. The exception to negative or neutral fishery performance indicators were the number of traps, median commercial length and un-adjusted price per pound which were all positive.

8 Reference Points

"Turn of the crank" reference points were calculated using CSM results as described in section 8.1, based on technique described in ASMFC 2006. In addition, per recruit biological reference points were calculated using the University of Maine model for comparison and discussion. The University of Maine basecase and alternate model results were used to calculate new recommended reference points that are modified from the 2006 assessment.

8.1 Current Reference Point Definition & Results

Current reference points were adopted by ASMFC in section 2.3.1 of Addendum VIII of Amendment 3 of the Interstate Fishery Management Plan for American Lobster. Stock status is determined by comparison of average F and average abundance during the most recent three years to stock-specific median values (computed for the fixed years 1982-2003 for GOM and GBK and 1984-2003 for SNE). Median abundance and median fishing mortality over these stock-specific fixed time periods are used as threshold reference points. Additionally, abundance and F targets are a minimum of one estimated standard error from the threshold (ASMFC 2006).

Based on these reference points, "overfishing" would occur if the average fishing mortality rate for the three most recent years were higher than the median threshold. A stock would be "depleted" if average abundance for the three most recent years fell below the median threshold level. In either of these cases, corrective management action should be implemented. Model estimates used to determine stock status in the 2006 assessment ("turn of the crank" reference points) are summarized in Table 8.1.1. Estimates were averaged over the last three terminal years minus one (2004-2006).

Fishing mortality-abundance (FN) plots are presented for lobster (sexes combined) in each stock assessment region. FN plots summarize trends in fishing mortality on the y-axis and trends in total abundance estimates on the x-axis. FN plots in this assessment include a vertical line showing median abundance and a horizontal line showing median fishing mortality. Quadrant plots are similar to tables because they show the number of observations in each of four conditions (see figure below). The upper lefthand quadrant indicates the stock is depleted and overfishing is occurring. The lower lefthand quadrant indicated the stock is depleted but overfishing is not occurring. The upper righthand quadrant indicates the stock is not depleted, but overfishing is occurring. The lower righthand quadrant indicates the stock is healthy (not depleted, overfishing not occurring).

Quadrants in FN plots

N < median N F > median F	N > median N F > median F
N < median N F < median F	N > median N F< median F

Based on CSM results and currently adopted reference points, the GOM stock is above the abundance threshold and target. The GOM stock is above the F threshold and target (Table 8.1.1). Therefore the GOM lobster stock is not depleted but overfishing is occurring. FN plots place the GOM stock in recent years in the upper righthand quadrant, showing that both N and F are above the median (Figure 8.1.1).

Similarly, the GBK stock is above the abundance threshold and above both the F threshold and target (Table 8.1.1). Although the stock is not depleted, abundance is below the target. Therefore the GBK lobster stock is not depleted but overfishing is occurring. FN plots place the GBK stock in recent years in the upper righthand quadrant, showing that both N and F are slightly above the median (Figure 8.1.1).

Based on CSM results and currently adopted reference points, the SNE stock is below the abundance threshold and target and above the F threshold and target (Table 8.1.1). Therefore the SNE lobster stock is both depleted and overfishing is occurring. FN plots place the SNE stock in recent years in the upper lefthand quadrant, showing that N is below the median and F is above the median (Figure 8.1.1).

8.2 Per recruit reference points

Per recruit reference points for total yield (male and female) (i.e. effective exploitation rates corresponding to F_{max} and $F_{0.1}$) and percent maximum egg production (e.g. the effective exploitation at $F_{10\%}$) were calculated in the University of Maine assessment model for comparison with model estimates. However, per recruit calculations are not useful for lobster at this time due to uncertainties in estimates from the new model (Section 8.3.1). The calculations were for a single cohort consisting of females and males over 75 years. The primary control variable in per recruit model calculations was full female fishing mortality. Calculations were for full female *F* value of zero to three in steps of 0.001. Reference points were identified by inspection of per recruit results in a table generated by the model.

Biological and fishery characteristics used in per recruit calculations were averages over the last three years in the model. In particular, averages were used for the sex ratio at recruitment (total female recruits/total recruits), proportions of female and female recruitment by season, natural mortality at size by quarter, fishery selectivity by sex and quarter, the ratio of male annual full *F* divided by female annual full *F*, and proportions of annual *F* by season and sex.

8.2.1 GOM

Per recruit reference points for GOM lobster were not very sensitive to alternate model data sources and configurations. The yield per recruit curve for sexes combined (Figure 8.2.1.1) and for females from the GOM basecase run did not exhibit a clear peak , whereas the male curve peaked at 0.3. Combined sex exploitation rate at F_{max} (where yield per recruit is maximized) was the same (0.34) across both basecase and alternate runs (Table 7.2.1.4). Exploitation rate at $F_{0.1}$ equaled 0.17 for all model runs except “Track fall trends with alternate CAL” and “Track spring trends” which produced lower estimates of 0.13and 0.1, respectively. In almost all runs, female spawning stock biomass per recruit analyses estimated effective exploitation at $F_{10\%}$ was 0.33, $F_{20\%}$ was 0.23, and $F_{30\%}$ was 0.17.

8.2.2 GBK

Per recruit reference points for GBK lobsters in this assessment are approximations because females and males were combined in the basecase model. The yield per recruit curve in the GBK basecase run was peaked (Figure 8.2.2.1). Reference points for GBK lobster were most sensitive to assumptions about natural mortality (M) and growth (Table 7.2.2.4). Effective exploitation at Fmax was 0.17 in the basecase run, 0.14 in the Male growth run and 0.1 (M=0.1 y-1) to 0.21 (M=0.2 y-1) in other runs. Effective exploitation at F10% was 0.25 in the basecase run, 0.22 in the Male growth run and ranged 0.17 (M=0.1 y-1) to 0.25 (M=0.2 y-1) in other runs. Effective exploitation at F0.1 was 0.08 in the basecase and Male growth runs and 0.05 (M=0.1 y-1) to 0.1 (M=0.2 y-1) in other runs. In contrast to these reference points, effective exploitation estimates during 1982-2007 (Table 7.2.2.3) from the basecase averaged 0.45.

8.2.3 SNE

The yield per recruit curve from the SNE basecase run peaked at F_{max} with an effective exploitation rate of 0.17 for sexes combined (Figure 8.2.3.1) and 0.14 for males; the female curve from the SNE basecase run did not exhibit a clear peak. Effective exploitation at $F_{0.1}$ was 0.06 for the basecase and increased with increasing trend in M (0.11 with a doubling trend in M; Table 7.2.3.4). Female spawning stock biomass per recruit analyses estimated effective exploitation at $F_{20\%}$ was 0.24 and $F_{30\%}$ was 0.16. Increasing trends in M produced higher effective exploitation rates at $F_{20\%}$ and $F_{30\%}$.

8.3 Recommended new reference points

8.3.1 Background

The SASC recommends revised reference points that are different than used in previous assessments and that are intended to improve communication between assessment scientists and their intended audience. Traditional stock assessments for many species, including previous lobster assessments based on the CSM and Life History models, use annual instantaneous fishing mortality rates that are applied to abundance of the fishable stock. Previous lobster assessments used fishable abundance to describe trends in the stock as a whole because the CSM model estimates fishable abundance. These traditional approaches are problematic in describing assessment results for lobster because of changes in the minimum legal size and changes in other factors (gear regulations and v-notching) that change fishery selectivity patterns and the basis of the fishable stock.

In this assessment, we recommend the use of "reference abundance" and "effective exploitation" as the primary descriptors of annual abundance and annual fishing pressure where presenting assessment results and per recruit reference points. Reference abundance is the number of lobster 78+ mm CL on January 1 plus the number that will molt and recruit to the 78+ CL group during the year. The 78 mm CL size was chosen because it is lower end of the 78-82 mm size group in the assessment model which contains the lowest minimum legal size (81 mm) for lobster in all three stocks. Effective exploitation is the annual catch in number divided by the reference abundance.

Consider a hypothetical example with 100 lobster 78+ mm CL on January 1. In this example, the natural mortality rate is M=0.15 per year, there are 10 new recruits to the 78+ mm size group at the beginning of summer due to the major molt, and 2 recruits to the 78+ mm size group at the beginning of fall due to the secondary molt. The reference abundance would be $100 + 10{*}e^{M/2} + 2{*}e^{3M/4} = 100 + 10{*}e^{0.075} + 2{*}e^{0.1125} = 100 + 10.8 + 2.2 = 113.0$ lobster on January 1. If the hypothetical catch in number were 50 lobster in the example, then the effective exploitation rate would be 50/113=0.44 per year.

Instantaneous rates are convenient for use in model calculations and accurately reflect the force of fishing on vulnerable size groups. However, they are relatively difficult to understand, particularly in cases like lobster where mortality is often high. Instantaneous rates may range from zero to very large values and are often larger than one for lobster. Casual readers may have trouble understanding or believing that fishing mortality rates can exceed one. Moreover, it is difficult to appreciate the practical consequences of changes in instantaneous rates when they are high. For example, with an instantaneous natural mortality rate of M=0.15 per year, a three-fold change in instantaneous mortality rates from F=1 to 3 changes the exploitation fraction (catch number / fishable abundance at the start of the year) from 0.59 to 0.91 or by about 35%.

It is also difficult to understand time series of fishable abundance and instantaneous fishing mortality rates when fishery selectivity patterns change due to management measures or fishing patterns. Consider a hypothetical case with two years in which recruitment and mortality is the same. In the second year, the minimum legal size is increased and fishable abundance is reduced by 30%. Catch also decreases by 30% in this hypothetical example because the instantaneous fishing mortality rate is unchanged. The practical effects of the change of minimum size are obscured by the traditional measures of fishable abundance and exploitation that have been used in the past for lobster. In particular, fishable abundance decreased by 30% while the instantaneous fishing mortality rate and conventional exploitation rate (catch numbers / fishable abundance) were unchanged even though total abundance was the same during both years and catch numbers declined by 30%. The conventional measures obscure the underlying situation in this example because the basis of the fishable stock changed and because the overall change in mortality was not reflected by a corresponding change in the instantaneous fishing mortality rate or conventional exploitation rate.

Revised "Overfishing" and "Depleted" definitions

Based on these reference points, "overfishing" would occur if the average effective exploitation rate for the three most recent years (2005-2007) were higher than the median threshold (computed for the fixed years 1982-2003 for GOM and GBK and 1984-2003 for SNE). A stock would be "depleted" if average reference abundance for the three most recent years fell below the median threshold level. In either of these cases, corrective management action should be implemented.

Critique of revised recommended reference points

In real lobster fisheries, the relationship between the effective exploitation rate and instantaneous fishing mortality rate will differ between the sexes if natural mortality rates differ between the sexes and if management measures such as discard of v-notched or ovigerous females differentially affect fishery selectivity and fishable abundance. The relationship will change over time as new management measures affecting fishery selectivity are introduced or as natural mortality varies. In all cases, however, the effective exploitation rate will measure the practical effects of fishing pressure in a consistent fashion using a summary statistic that ranges from zero to one.

The main disadvantage of effective exploitation rates is that they depend on both recruitment and fishing pressure. In particular, effective exploitation rates will increase or decrease with recruitment and the abundance of lobster between 78 mm CL and the minimum legal size. An increase in effective exploitation accurately reflects deteriorating conditions for the stock but may be due to low recruitment instead of increased fishing pressure, and vice-versa.

Effective exploitation rates have an important mathematical property related to the confounding effects of recruitment and fishing pressure. In particular, effective exploitation estimates from a stock assessment model are not unique relative to fully recruited fishing mortality rates because the two types of measures do not have a one-to-one relationship. In contrast, the two measures have a unique, one-to-one relationship when calculated on an equilibrium context in a per recruit model.

Variability in recruitment may make effective exploitation rates highly variable but this was not a problem for lobster in this assessment. Effective exploitation estimates for lobster from the University of Maine model were reasonably smooth. In addition, status determinations were based on means and medians, which are much less variable than estimates for individual years (e.g. mean effective exploitation during 2005-2007 compared to median effective exploitation during 1982-2003).

Another caution regarding both new and old reference points is that important information about the stock is lost when "averaging" exploitation of combined sexes. Exploitation rates for combined sexes may exclude important information about stock status for lobsters, specifically very high rates of exploitation on males. Current harvest regulations provide different levels of protection by size and sex. Males are legally harvested from the size they enter the fishery (minimum CL) until a maximum size (if it exists). Female harvest is similarly controlled, but they are protected from being landed when they are ovigerous and v-notched. These measures alter the selectivity (aka partial recruitment) pattern in addition to the size selectivity. As a result, the application of an equal level of trapping for females and males would result in lower exploitation of females and a population sex ratio that is skewed toward females. When expressing exploitation in terms of combined sexes, lower exploitation (and higher abundance) of females will obscure higher exploitation and lower abundance of males in the population. Therefore, combined sex reference points will misrepresent the effect of fishing on the individual sexes. This could be one reason the sex ratios are dominated by females.

An additional concern with combined sex reference points is that information about female conservation at different levels of exploitation is lost. Actual selectivity pattern of females changes with exploitation and a higher rate of exploitation lessens the effect of egg-bearing protection. If a female is egg-bearing for one year out of the total years she spends at a given size, higher exploitation will remove the potential of extrusion and prevent her from growing to the another period of protection (being egg-bearing at a larger size). The prevention of allowing females to extrude (and thus be protected) also affects the v-notching process because it is mainly applied to berried females. As a result, at relatively low exploitation females move in and out of being selected, rather than following an ascending pattern. The higher the removals, the more the pattern becomes a traditional logistic progression to full (1.0) selectivity.

Uncertainty in Stock Status

The new model proved useful in analyzing the sometimes conflicting lobster stock assessment data. However, long-standing uncertainty about lobster population dynamics was not resolved. In particular, exploitation estimates in this assessment from the new model were substantially higher than corresponding per recruit reference points (i.e. $F_{10\%}$) for extended periods of time while stock abundance in the GOM area increased rapidly, abundance in GBK was stable or increasing, and while abundance in SNE increased and then decreased. The degree of mismatch between estimated high exploitation levels and increasing stock trends in GOM and GBK indicates that the estimates of exploitation are too high (and stock abundance estimates are too low) and/or that biological reference points are too low (stock productivity is higher than estimated). This pattern is also evident in previous lobster assessments (e.g. ASMFC 2006). This nagging problem was not solved by any of the advances in this assessment (i.e. estimation of stock status and reference points in the same model, improved metrics for characterizing exploitation when changes in fishery selectivity occur, and utilization of a wider range of data sources), or by application of the new model itself.

The point estimates of effective exploitation and reference abundance from the new model in this assessment are useful as trend indicators but probably not as estimates in absolute terms. For example, a change in effective exploitation from 0.2 to 0.4 would indicate that the variable in question doubled but would not necessarily indicate that either 0.2 or 0.4 was a reasonable estimate of the underlying true values. Uncertainties in estimates and/or reference points stem from many of the same sources including growth parameters, natural mortality and recruitment dynamics at low or high stock sizes. Additional studies to characterize growth and natural mortality rates or new theory to explain the continued existence of productive lobster stocks under extremely heavy fishing will likely be required to resolve the problem.

In view of these issues, the new model was used to evaluate stock status relative to trends during a reference period for each stock, but not relative to absolute abundance or exploitation-based reference points (e.g. B_{msy} or $F_{10\%}$). As described in ASMFC 2004, the trend based reference points for lobster have proven insensitive to a wide range of assumptions about natural mortality, do not depend on the estimated scale of model estimates, and are expected to give similar results using a wide range of models or survey data in the absence of a model. The major disadvantage with the trend based reference points is that there is no guarantee that median conditions since the early 1980's are optimal or even appropriate for lobster. The reference period used in this assessment (1982-2003 for GOM and GBK; 1984-2003 for SNE) is a relatively short time series. These 20-22 years of data may not be reflective of the entire productive range of the stock.

8.3.2 Current Status of the Stocks

GOM

Based on University of Maine model results and revised reference points, the GOM stock is above the reference abundance threshold and below the effective exploitation threshold (Table 7.2.1.4). Quadrant plots (Figure 8.3.1) place the GOM stock in the lower righthand region in recent years, demonstrating that estimated reference abundance is above the median and estimated effective exploitation is slightly below the median. ***Therefore the GOM lobster stock is not depleted and overfishing is not occurring.***

Quadrant interpretations

N < median N mu > median mu	N > median N mu > median mu
N < median N mu < median mu	N > median N mu < median mu

In general, both University of Maine model estimates and non-model based stock indicators suggest that abundance, spawning stock biomass, and recruitment are high in GOM and the stock appears to be healthy at present. However, assessment results suggest careful consideration of key issues:

1. Effective exploitation is likely at or near the long term median. Given uncertainty in model estimates and population variability, it is possible that overfishing may be occurring now or will occur between now and the next assessment. In addition, CSM model results indicate that overfishing is occurring in the GOM.
2. Record high landings have been supported by a long period of excellent recruitment. Recruitment failures could rapidly cause the status of the stock to worsen.
3. Effort levels in recent years are the highest observed since 1982 (both in number of traps and soak time indicators).
4. Statistical area 514, waters off the coast of MA, has continued to experience declines in recruitment and abundance since the last assessment.
5. Relatively few females have the opportunity to spawn at least once prior to harvest given only 12% of lobster are mature at the minimum legal size.
6. The NEFSC fall survey index of relative abundance has steadily declined in recent years, indicating a potential decline in population abundance offshore.
7. CSM results, which track closely trends in relative abundance trends from the NEFSC and MA DMF surveys, indicate that the GOM stock abundance is declining and fishing mortality is increasing in recent years.

GBK

Based on University of Maine model results and new proposed reference points, the GBK stock is above the reference abundance threshold and below the effective exploitation threshold (Table 7.2.2.4). Quadrant plots place the GBK stock in recent years in the lower righthand quadrant, demonstrating that estimated reference abundance is above the median and estimated effective exploitation is below the median (Figure 8.3.1). ***Therefore the GBK lobster stock is not depleted and overfishing is not occurring.***

In general, both University of Maine model estimates and non-model based stock indicators suggest that abundance and spawning stock biomass are high in GBK and the stock appears to be healthy at present. However, assessment results suggest careful consideration of key issues:

1. Sex ratio of the population in recent years is largely skewed toward females for unknown reasons (~80% from 2005 to 2007). If sperm limitation is a concern for GBK lobster, the stock could experience recruitment problems in the future.
2. Relatively few females have the opportunity to spawn at least once prior to harvest given only 7% of lobster are mature at the minimum legal size.

3. Lack of adequate sea and port sampling data may be hindering the ability to estimate numbers landed length structure and sex ratio of the catch.
4. Recent trends in fall and spring survey data are not consistent; if the fall survey is correct then stock levels may be lower. In addition, CSM model results indicate that overfishing is occurring (recent $F = 0.27$ is above threshold of 0.26).
5. Recent landings (in weight) during 2005 to 2008 are at record levels and more than double that of 1982-2000; these record catch levels may not be sustainable.

SNE

Based on University of Maine model results and new proposed reference points, the SNE stock is below the reference abundance threshold and effective exploitation threshold (Table 7.2.3.4). Quadrant plots place the SNE stock in recent years in the lower lefthand quadrant, demonstrating that estimated reference abundance is below the median and estimated effective exploitation is below the median (Figure 8.3.1). ***Therefore the SNE lobster stock is depleted but overfishing is not occurring.***

In general, University of Maine model estimates, CSM estimates, and non-model based stock indicators suggest that abundance, spawning stock biomass, and recruitment are at low levels in SNE. The stock has not rebuilt since the last assessment and is still in poor condition. Assessment results suggest careful consideration of key issues:

1. The estimated upturn in abundance and spawning stock biomass in recent years may be due to the 2000-2005 RI v-notch program. However, any positive effects may be short-lived. A longer and more geographically widespread v-notch program would be necessary to increase spawning stock abundance enough to boost recruitment and allow the stock to rebuild.
2. All fishery performance indicators are negative or neutral in recent years except median length and unadjusted price per pound. The 2005-2007 average for trap number is double that recorded in 1981-1983, a period of similar landings, but comparable to trap totals in the late 1980's and well below the median.

9.0 Research Recommendations

University of Maine Model Development

The University of Maine model used for this assessment should be revised if the model will be used for future lobster assessments. Where possible, more biological realism from the Life History model should be incorporated. A complete list of revisions will be generated following peer review, but will likely include options to:

- Estimate the growth matrix
- Include any number of surveys
- Specify number of years across which to conduct the assessment (e.g. to ease performance of sensitivity and retrospective analyses)
- Estimate time varying catchability
- Separate male and female estimated selectivity components
- Estimate trend in M

In addition, the following tasks should be completed:

- Continue to explore effects of natural and fishing mortality on growth
- Examine projection capabilities
- Explore further the model's MCMC and likelihood profile uncertainty estimation capabilities
- Improve efficiency (reduce duplication of same/similar functions)
- Reorganize report section
- Retest model with simulated data to error check all the changes that have been made

Program Research

New research and expansion of existing monitoring programs in the following areas would provide information needed to improve future stock assessments:

1 - Fishery-Dependent Information

Accurate and comparable landings are the principal data needed to assess the impact of fishing on lobster populations. The quality of landings data has not been consistent spatially or temporally. Aligning stock management areas with area designations for landings and management is necessary. Enhanced sea sampling and port sampling to create a more complete record of biological characteristics of the catch and harvest would also improve the usefulness of these data. This is especially needed in offshore waters. In addition, investigations are needed to determine where lobster are being caught and if and how this changes over time. A lot of progress has been made recently by improvements in landing reporting programs (SAFIS, 10% mandatory reporting, and mandatory vessel trip reports in some areas) and increased port and sea-sampling programs. However, many of these gains are about to be lost due to lack of funding. There is no funding for the offshore port-sampling program and shrinking funds for sea-sampling programs will impact the spatial and temporal extent of sampling efforts. These types of programs are essential for accurate lobster assessments and must have dedicated funding.

2 - Growth

The apparent mismatch of biological reference points and current stock status from this and previous assessments, poor model fits to certain length data sources in the new assessment, and samples of large lobster from Georges Bank with clean shells (no fouling or shell disease), suggest that growth may not be characterized correctly. All of the information used to estimate molt frequency and much of the information used to estimate molt increments was collected from hatchery reared lobster. Hatchery growth may not be an accurate model of growth in the wild, particularly for large lobster. Research and tagging programs should be developed to generate better more accurate information on growth, particularly for large lobster.

3 - Fishery-Independent Information

There is a need to develop consistent techniques that monitor distribution and abundance of lobster independent of the fishery. Current methods (e.g. trawls) are limited in area (gear conflicts) and do not target primary lobster habitat (unable to access complex bottom). A coastwide ventless trap survey was initiated in 2006 to develop a time series of lobster relative abundance and recruitment while attempting to eliminate the biases identified in conventional surveys. The survey was conducted from 2006 to 2008 from the Gulf of Maine to Long Island Sound. Funding is necessary to continue the survey.

These data will need to be calibrated for use alongside trawl survey indices in future assessment models. Also, the NEFSC trawl survey data from old and new vessels (Albatross vs. Bigalow) will need to be calibrated before these data can be used in the next assessment.

Little is known about the cause and implications of the sudden recent increase in proportion females in offshore GOM and GBK. Given the potential for sperm limitation and decreased stock productivity that could result, more research is needed on this phenomenon.

Current stock boundaries separate the US and Canadian lobster population into semi-discrete stocks, so it is necessary to understand how much adult and larval exchange occurs between stocks and if this exchange represents a significant recruitment subsidy to US stocks. How do differing management strategies in adjacent stocks fit if exchange rates are high? This is particularly important given the similarities in the increasing size and proportion of female in the offshore Gulf of Maine and Georges Bank stocks.

4 - Age

All assessments of lobster stock status have been based on analyses of length data. Age is assumed by applying per-molt growth increments and molt frequencies to the length data. Based on these analyses, the American lobster has been treated as an extremely long-lived animal, reaching a reproductive maximum at a relatively old age. These assumptions are based on no actual age data. Applying aging techniques developed in England and Australia for lobster and other crustaceans would greatly improve our understanding of how many year-classes support the current trap fishery, how length relates to age, and how variable the age structure is over stock area and time. Research has been initiated on ageing techniques in New England in ME and CT. This work should be continued and expanded.

5 - Ecosystem-based Management

NOAA's 2004 Strategic Plan for Fisheries Research recommends the inclusion of ecosystem and environmental information in all stock assessments. Further examination of lobster mortality not related to the fishery would provide a better understanding of factors limiting productivity and longevity. Research has been conducted in Southern New England in response to the Long Island Sound lobster die off elucidating the affects of temperature, pesticides and shell disease. Initial modeling work has been developed relating North Atlantic Oscillation (NAO) and water temperature shifts to larval and adult survival. Additional topics should include: predator/prey interactions and community structure (e.g. gut content analyses), directed tagging studies to estimate natural mortality, climatic shifts in ocean currents and temperature in all stock areas, and toxic substances causing chronic stress or disease. Investigations of stock unit carrying capacity should be explored, specifically: How should lobster be managed in a stock whose carrying capacity has declined or may be declining? What metric should be used to measure carrying capacity for lobster? How would a climate- induced range contraction be defined, and how should a stock whose range has contracted be managed?

6 - Investigation of Trans-boundary Assessments

Investigate conducting joint US and Canadian assessments. The two most productive U.S. stocks, (Gulf of Maine and Georges Bank), are shared with Canada. The two stock areas should be assessed as a jointly, and linkages between US and Canadian fisheries and the dynamics of different management strategies on shared stocks should be examined.

7 - Investigation of Historical Levels of Stock Production

One limitation of current trend based reference points is the period covered by the assessment. Investigations of past levels of stock size and size structure could provide additional insight into setting reference points that relate to the full range of stock productivity. Current status should be compared to some reasonably high stable period of stock production. Otherwise current stock status may be compared to a median value that is a continued diminishing return.

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Table 1.2. 2008 regulations by lobster conservation management area.

Management Measure	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	OCC
Trap Limits/Numbers	Trap Cap (800)	Hist. Part with 800 trap max*	Hist. Part.	Hist. Part.	Hist. Part.	Hist. Part.*	Hist. Part.*
Gauge Size '08	3-1/4"	3-3/8"	3-1/2"	3-3/8"	3-3/8"	3-5/16"*	3-3/8"
Vent '08 Rect.	1-15/16x 5-3/4"	2 x 5-3/4"	2 x 5-3/4"	2 x 5-3/4"	2 x 5-3/4"	1-15/16x 5-3/4"	2 x 5-3/4"
Vent '08 Cir.	2-7/16"	2-5/8"	2-5/8"	2-5/8"	2-5/8"	2-7/16"	2-5/8"
V-notch requirement	Mandatory for all eggers	None	Mandatory for all eggers above 42°30'	None	None	None	None
'08 V-Notch Definition (possession)	Zero Tolerance	1/8" with or w/out setal hairs[1*]	1/8" with or w/out setal hairs[1*]	1/8" with or w/out setal hairs[1*]	1/8" with or w/out setal hairs[1*]	1/8" with or w/out setal hairs[1]*	1/4" without setal hairs
'08 Max. Gauge (male & female)	5"	5 ¼"*	7"[2*]	5 ¼"[*3]	5 ¼"[*3]	5 ¼"*	None

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[1] A v-notched lobster is defined as any female lobster that bears a notch or indentation in the base of the flipper that is at least as deep as 1/8 inch, with or without setal hairs. It also means any female which is mutilated in a manner that could hide, obscure, or obliterate such a mark.

[2] In 2009 and 2010, Area 3 maximum size shall be lowered 1/8" per year for two years, resulting in a maximum gauge of 6 3/4" on July 1, 2010.

* Regulation has not been implemented by NOAA Fisheries but has been implemented by state therefore most restrictive rule applies in state waters.

[3] Federal maximum size prohibition applies only to female lobsters, and the Federal Area 5 maximum size remains at 5 ½"

Table 2.2.2.1. Molt increment-carapace length (CL) models for male and female lobster in the GOM, GBK and SCCLIS stock areas fit to tagging data for each region based on assumptions described in footnotes.
Predicted increments at 50mm CL are shown for comparison.

Region	Sex	Increment at 6 mm CL (mm)	CL at Inflection (κ, mm)	Maximum Mean Increment (mm)	Increment at 50 mm CL (mm)	SD (mm)	Number Tagging Observations	Minimum CL in Data (mm)	Maximum CL in Data (mm)	Intercept Parameter (α)	Slope Parameter (β)	Source of Tagging Data
GOM	Female	2	82	12	8	2.0	201	25	80	1.2288	0.1285	ME DMR
GOM	Male	2	95	14	8	2.2	289	25	79	1.2236	0.1294	ME DMR
GBK	Female	2	75	14	10	1.7	106	68	140	0.9657	0.1724	Cooper and Uzzman
GBK	Male	2	87	18	11	2.1	63	63	115	0.8319	0.1947	Cooper and Uzzman
SNE	Female	2	64	9	7	2.3	293	30	94	1.3006	0.1166	RI Inshore and Offshore (T. Angel & K. Castro)
SNE	Male	2	74	11	8	2.3	482	53	98	1.1775	0.1371	RI Inshore and Offshore (T. Angel & K. Castro)

Notes:

1) Inflection point for females in all areas set at CL where 10% are sexually mature (a rough estimate of the size at onset of sex maturity).
2) Inflection point for males in all areas set at the inflection point for females * P, where P = 1.16 was estimated.
3) Maximum mean increment estimated for females in all stocks.
4) Maximum mean Increment for males = maximum female increment * J, where J = 1.26 was estimated.
5) Increment at 6 mm CL set at 2 mm based on Massachusetts hatchery data.
6) Tag data for lobsters at liberty longer than 1 year were omitted.
7) "Outliers" (including potential double molters) were excluded if the absolute value of standardized residuals from robust linear regression lines was > 6.
8 The standard deviation (SD) is for residuals around the assumed molt increment-caprapace length model.
9) By agreement, the average standard deviation (2.1 mm) will be used in modeling growth for both sexes in all areas.
10) Maximum mean increments or females (at large sizes), a single offset parameter for male inflection points, and a single offset parameter for male maximum mean increments were estimated by minimizing sums of squares (5 parameters estimated).

Table 2.4.1. Assignment of surveys to stock regions used in modeling.

Stock region	Surveys	Strata
GOM	NEFSC - GOM, Fall	01270-01300; 01360 01400; 03590 03610; 03650 03660 (NEFSC survey strata)
	MA_DMF - 514, Fall	09250 and 09360 (MA survey strata)
	ME_DMR, Fall	1-3 (ME survey strata)
GBK	NEFSC - GBK, Spring	01090-01250 (NEFSC survey strata)
	NEFSC - GBK, Fall	01090-01250 (NEFSC survey strata)
SNE	NEFSC - SNE, Fall	01010-01080; 01610-01760; 03450-03550 (NEFSC survey strata)
	CT_DEP - Fall	See CTDEP (2004, p. 63 and Fig. 2.1)
	RI_DMF - Fall	1-11 (RI survey strata)

Table 2.4.2. Assignment of statistical areas for landing data to stock regions used in modeling.

Stock region-survey area	Statistical Reporting Areas for Landings
GOM	464, 465, 467, 511, 512, 513, 514, 515
GBK	521, 522, 523, 524, 525, 526, 541, 542, 543, 561, 562
SNE	533, 534, 537, 538, 539, 611, 612, 613, 614, 615, 616, 621, 622, 623, 624, 625, 626, 627, 631, 632, 635, 701

Table 2.6.1. Prevalence of shell diseased lobster observed in commercial trap catches by statistical area. Percentages are annual for each statistical area.

State:	Connecticut New York	Rhode Island		Massachusetts			New Hampshire	Maine
Area:	611	616	539	538	521	514	513	511-513
Year								
1992	0.6%							
1993	0.5%							
1994	1.0%							
1995	1.0%							
1996	1.6%	0	0.3%					
1997	2.3%	0	4.3%					
1998	2.1%	0.2%	19.0%	23.8%				
1999	3.9%	0.8%	20.3%	20.5%				
2000	3.8%	1.7%	21.8%	9.4%	0	3.7%		
2001	5.5%	2.2%	22.6%	11.6%	2.2%	6.5%	<0.05%	
2002	9.2%	3.1%	30.4%	25.9%	0.4%	5.5%	0.2%	
2003	11.3%	3.1%	24.9%	29.0%	0.9%	4.2%	0.2%	<0.05%
2004	6.0%	2.6%	27.9%	11.5%	0.5%	1.7%	0.2%	<0.05%
2005	7.2%	2.3%	26.2%	14.3%	0.4%	2.3%	0.1%	<0.05%
2006	5.1%	1.7%	27.6%	23.9%	0	1.2%	0.1%	0.1%
2007	7.8%	5.1%	18.0%	24.6%	0.6%	3.7%	0.1%	0.1%

Table 3.2.1.1. Number of commercial lobster licenses issued by state, 1981 - 2007.

Year	CT	MA	ME	NH	NJ	NY	RI	Total
1981	659	2,118	8,548	302	*NA*	393	*NA*	12,020
1982	678	2,052	8,891	323	*NA*	380	*NA*	12,324
1983	649	2,169	8,895	337	*NA*	446	*NA*	12,496
1984	642	2,367	8,730	307	*NA*	521	*NA*	12,567
1985	693	2,417	7,879	302	*NA*	556	*NA*	11,847
1986	623	2,514	6,875	332	*NA*	559	*NA*	10,903
1987	578	2,641	6,730	313	*NA*	551	*NA*	10,813
1988	612	2,627	6,804	318	*NA*	959	*NA*	11,320
1989	595	2,556	7,215	327	*NA*	945	*NA*	11,638
1990	606	2,465	6,706	299	*NA*	994	1,177	12,247
1991	611	2,399	6,940	286	*NA*	1,067	1,270	12,573
1992	547	2,357	6,162	267	*NA*	1,171	1,394	11,898
1993	544	2,338	6,176	263	*NA*	1,211	1,007	11,539
1994	499	2,260	6,196	287	*NA*	1,265	980	11,487
1995	513	2,205	7,449	311	*NA*	995	1,317	12,790
1996	445	2,149	7,027	310	*NA*	932	1,075	11,938
1997	427	2,145	7,101	303	*NA*	888	1,089	11,953
1998	441	2,099	6,887	311	*NA*	761	1,597	12,096
1999	419	2,099	6,753	297	*NA*	746	1,087	11,401
2000	389	2,075	6,880	309	87	657	1,487	11,884
2001	352	2,070	6,838	325	95	600	1,512	11,792
2002	345	2,086	6,792	339	109	554	1,398	11,623
2003	286	2,057	6,812	349	109	506	1,625	11,744
2004	293	1,810	6,779	356	109	477	1,546	11,370
2005	274	1,744	6,949	374	109	458	1,455	11,363
2006	277	1,683	6,809	373	109	428	1,378	11,057
2007	251	1,626	6,691	362	109	412	1,312	10,763

mean	11,757
median	11,792
min	10,763
max	12,790

Table 3.2.1.2. Number of trap hauls reported fished by state in the each stock unit.

	Gulf of Maine				Georges Bank				Southern New England				
Year	**Maine**	**Massachusetts**	**New Hampshire**	**GOM Total**	**Rhode Island**	**Massachusetts**	**New Hampshire**	**GBK Total**	**Connecticut**	**Massachusetts**	**New York**	**Rhode Island**	**SNE Total**
1981									906,085	*NA*	*NA*	*NA*	*NA*
1982	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	812,129	*NA*	*NA*	*NA*	*NA*
1983	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	1,296,230	*NA*	*NA*	*NA*	*NA*
1984	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	1,477,438	*NA*	*NA*	*NA*	*NA*
1985	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	1,475,350	*NA*	*NA*	*NA*	*NA*
1986	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	1,380,421	*NA*	*NA*	*NA*	*NA*
1987	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	1,524,902	*NA*	*NA*	*NA*	*NA*
1988	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	1,688,491	*NA*	*NA*	*NA*	*NA*
1989	*NA*	*NA*	1,702,208	*NA*	*NA*	*NA*	*NA*	*NA*	1,749,483	*NA*	*NA*	*NA*	*NA*
1990	*NA*	*NA*	1,367,194	*NA*	*NA*	*NA*	*NA*	*NA*	2,078,540	*NA*	*NA*	*NA*	*NA*
1991	*NA*	*NA*	1,228,120	*NA*	*NA*	*NA*	*NA*	*NA*	2,057,914	*NA*	*NA*	*NA*	*NA*
1992	*NA*	*NA*	1,150,165	*NA*	*NA*	*NA*	*NA*	*NA*	2,235,864	*NA*	*NA*	*NA*	*NA*
1993	*NA*	*NA*	1,735,908	*NA*	*NA*	*NA*	*NA*	*NA*	2,196,723	*NA*	*NA*	*NA*	*NA*
1994	*NA*	17,599,271	1,323,607	*NA*	*NA*	978,329	*NA*	*NA*	2,029,217	2,203,777	*NA*	*NA*	*NA*
1995	*NA*	16,806,795	1,513,985	*NA*	*NA*	825,963	*NA*	*NA*	1,954,208	2,061,991	*NA*	*NA*	*NA*
1996	*NA*	15,939,904	1,534,368	*NA*	*NA*	860,423	*NA*	*NA*	2,267,464	2,092,869	*NA*	*NA*	*NA*
1997	*NA*	14,860,306	1,645,640	*NA*	*NA*	851,078	*NA*	*NA*	2,526,867	2,280,035	*NA*	*NA*	*NA*
1998	*NA*	14,307,054	1,408,104	*NA*	*NA*	891,098	*NA*	*NA*	3,020,704	2,305,779	*NA*	*NA*	*NA*
1999	*NA*	14,494,605	1,495,924	*NA*	*NA*	825,083	*NA*	*NA*	2,619,109	2,214,906	*NA*	*NA*	*NA*
2000	*NA*	15,322,790	1,371,704	*NA*	*NA*	723,238	*NA*	*NA*	1,752,345	1,722,371	*NA*	*NA*	*NA*
2001	*NA*	14,129,232	1,781,495	*NA*	*NA*	904,641	*NA*	*NA*	1,907,920	1,674,394	*NA*	*NA*	*NA*
2002	*NA*	14,815,428	1,309,933	*NA*	*NA*	977,778	*NA*	*NA*	1,553,256	1,783,840	*NA*	*NA*	*NA*
2003	*NA*	14,167,004	1,346,460	*NA*	*NA*	918,265	*NA*	*NA*	1,279,213	1,320,210	*NA*	*NA*	*NA*
2004	*NA*	13,621,066	1,684,730	*NA*	*NA*	987,522	227,669	1,215,191	1,204,880	1,202,607	*NA*	*NA*	*NA*
2005	*NA*	12,671,180	1,459,467	*NA*	*NA*	1,033,427	226,290	1,259,717	1,213,451	1,191,289	*NA*	*NA*	*NA*
2006	*NA*	13,122,418	1,673,802	*NA*	*NA*	1,043,863	317,850	1,361,713	1,314,139	1,326,014	*NA*	*NA*	*NA*
2007	*NA*	12,874,812	1,631,313	*NA*	*NA*	1,017,800	308,226	1,326,026	1,068,458	1,187,833	*NA*	*NA*	*NA*

Table 3.2.1.3. State Landings in metric tons (mt) from 1981 to 2007.
2007 landings are preliminary estimates.

Year	ME	NH	MA	RI	CT	NY	NMFS	Total
1981	10,266	360	5,180	849	366	404	324	17,749
1982	10,310	366	5,110	1,440	399	509	457	18,591
1983	9,836	594	5,837	2,320	750	548	419	20,304
1984	8,866	712	5,646	2,386	815	593	530	19,548
1985	9,129	542	6,216	2,332	626	563	600	20,008
1986	8,938	427	5,668	2,571	569	643	627	19,443
1987	8,958	570	5,832	2,412	713	520	722	19,727
1988	9,861	508	5,886	2,159	872	807	771	20,864
1989	10,600	649	7,097	2,625	942	1,064	997	23,974
1990	12,732	752	7,696	3,292	1,200	1,556	1,066	28,294
1991	13,966	817	7,290	3,377	1,213	1,419	799	28,881
1992	12,170	694	6,818	3,068	1,149	1,203	573	25,675
1993	13,575	768	6,546	2,825	987	1,210	445	26,356
1994	17,667	749	7,384	2,937	974	1,794	271	31,776
1995	16,878	832	7,280	2,432	1,153	3,018	301	31,894
1996	16,367	741	6,967	2,402	1,310	4,268	313	32,368
1997	21,330	641	6,855	2,630	1,573	4,027	406	37,462
1998	21,336	542	6,009	2,548	1,685	3,582	338	36,040
1999	24,265	626	7,217	3,700	1,177	2,927	447	40,359
2000	25,924	776	6,818	3,133	632	1,308	463	39,054
2001	22,053	920	5,553	2,020	603	931	291	32,371
2002	28,860	921	6,223	1,740	484	653	133	39,014
2003	24,935	889	5,184	1,615	304	429	113	33,469
2004	32,466	1,293	5,312	1,388	293	539	193	41,484
2005	31,176	1,160	5,195	1,440	324	560	198	40,053
2006	32,961	1,181	5,486	1,702	360	596	240	42,526
2007	28,645	1,108	4,950	1,482	258	412	345	37,200

Table 3.2.1.4. Difference in landings (mt) from 2006 assessment (2008 - 2006).

Year	ME	NH	MA	RI	CT	NY	NMFS	Net Change
1981	0	0	0	34	0	0	0	0.2%
1982	0	0	1	60	0	0	0	0.3%
1983	0	0	0	0	0	0	0	0.0%
1984	0	0	1	1	0	0	0	0.0%
1985	0	0	1	0	0	0	0	0.0%
1986	0	0	0	0	0	0	0	0.0%
1987	1	0	1	0	0	0	0	0.0%
1988	0	0	-1	0	0	-1	0	0.0%
1989	0	0	0	0	0	0	0	0.0%
1990	0	0	0	0	0	0	0	0.0%
1991	0	0	0	-1	0	0	0	0.0%
1992	0	0	0	0	0	0	0	0.0%
1993	1	0	0	-1	0	0	0	0.0%
1994	0	0	0	0	0	0	-295	-0.9%
1995	1	0	0	287	0	0	-394	-0.3%
1996	0	1	0	284	-1	0	-51	0.7%
1997	1	0	0	311	0	0	-549	-0.6%
1998	0	0	0	301	0	-285	-480	-1.3%
1999	0	-1	1	0	0	-276	-368	-1.6%
2000	-29	1	0	0	-1	-49	-134	-0.5%
2001	0	1	1	0	-1	0	0	0.0%
2002	0	1	0	0	0	0	4	0.0%
2003	-51	0	94	45	0	-1	5	0.3%

Table 3.2.2.1. Gulf of Maine landings in metric tons by state from 1981 to 2007. 2007 landings are preliminary estimates.

Year	MA	ME	NH	RI	Total
1981	4,152	10,266	360	0	14,777
1982	3,992	10,310	366	0	14,669
1983	4,638	9,836	594	0	15,069
1984	4,219	8,866	712	0	13,797
1985	4,890	9,129	539	0	14,558
1986	4,454	8,935	427	0	13,816
1987	4,425	8,958	570	0	13,952
1988	4,328	9,861	508	0	14,696
1989	5,459	10,600	649	0	16,708
1990	5,761	12,732	752	0	19,245
1991	5,420	13,966	817	13	20,216
1992	4,875	12,170	694	0	17,738
1993	4,554	13,575	673	1	18,802
1994	5,392	17,667	596	0	23,655
1995	5,375	16,878	710	0	22,962
1996	5,127	16,367	628	0	22,122
1997	4,750	21,330	544	0	26,624
1998	3,973	21,336	460	0	25,769
1999	5,115	24,265	525	0	29,905
2000	5,208	25,924	658	0	31,797
2001	3,664	22,053	780	0	26,497
2002	4,158	28,860	781	0	33,800
2003	3,506	24,935	682	6	29,129
2004	3,553	32,466	968	34	37,021
2005	3,227	31,176	622	33	35,058
2006	3,573	32,961	680	83	37,297
2007	3,266	28,645	720	69	32,700
1981 to 2003 mean	4,671	15,601	610	1	20,883
2005 to 2007 mean	3,355	30,927	674	62	35,019
3 yr. % change from mean	-28.17%	98.24%	10.53%	7005.21%	67.69%

Table 3.2.2.2. Number of traps reported fished by state in the Gulf of Maine stock unit.

Year	Maine	Massachusetts	New Hampshire	Total
1982	2,143,000	247,415	*NA*	2,390,415
1983	2,340,000	259,642	*NA*	2,599,642
1984	2,175,000	275,165	*NA*	2,450,165
1985	1,766,000	313,758	*NA*	2,079,758
1986	1,595,000	331,713	*NA*	1,926,713
1987	1,909,000	356,169	*NA*	2,265,169
1988	2,053,000	356,689	*NA*	2,409,689
1989	2,001,000	351,584	44,715	2,397,299
1990	2,130,000	378,703	37,294	2,545,997
1991	2,015,000	399,010	30,781	2,444,791
1992	2,012,000	388,415	34,406	2,434,821
1993	1,806,000	370,641	46,390	2,223,031
1994	2,408,000	373,641	40,081	2,821,722
1995	2,605,000	377,305	44,020	3,026,325
1996	2,470,248	389,492	48,868	2,908,608
1997	2,593,271	383,506	60,388	3,037,165
1998	2,820,648	389,933	48,123	3,258,704
1999	3,038,604	379,970	43,448	3,462,022
2000	2,773,361	384,581	44,931	3,202,873
2001	2,959,969	375,807	53,074	3,388,850
2002	3,080,844	394,820	40,186	3,515,850
2003	3,189,471	383,055	50,967	3,623,493
2004	3,218,389	360,112	48,316	3,626,817
2005	3,245,694	344,104	52,450	3,642,248
2006	3,248,804	343,291	51,090	3,643,185
2007	3,229,148	339,597	53,075	3,621,820

Table 3.2.3.1. Georges Bank landings in metric tons by state from 1981 to 2007. 2007 landings are preliminary estimates.

Year	CT	MA	ME	NH	NMFS	NY	RI	Total
1981	0	596	0	0	0	25	543	1,165
1982	0	590	0	0	0	1	710	1,301
1983	0	591	0	0	5	0	852	1,447
1984	0	749	0	0	0	0	747	1,496
1985	0	746	0	3	0	0	740	1,489
1986	0	624	3	0	0	0	616	1,243
1987	0	828	0	0	0	0	488	1,316
1988	0	931	0	0	0	95	391	1,417
1989	0	964	0	0	0	0	362	1,326
1990	0	1,026	0	0	0	7	397	1,431
1991	0	936	0	0	0	0	644	1,580
1992	0	1,131	0	0	0	0	572	1,703
1993	0	1,124	0	95	0	0	326	1,545
1994	0	1,013	0	153	0	0	180	1,346
1995	0	925	0	122	0	0	167	1,214
1996	1	864	0	112	0	0	165	1,141
1997	1	937	0	97	0	0	180	1,215
1998	1	938	0	82	0	0	175	1,196
1999	0	1,112	0	102	0	0	227	1,441
2000	4	871	0	117	0	0	192	1,184
2001	4	1,140	0	139	0	0	124	1,407
2002	2	1,315	0	139	0	0	107	1,563
2003	1	1,214	0	206	0	0	365	1,787
2004	3	1,310	0	326	0	8	333	1,979
2005	1	1,461	0	537	0	4	390	2,394
2006	1	1,369	0	502	0	5	363	2,240
2007	11	1,298	0	387	0	8	359	2,064
1981 to 2003 mean	1	985	N/A	116	N/A	6	397	1,505
2005 to 2007 mean	4	1,376	N/A	476	N/A	6	371	2,233
3 yr. % change from mean	305.53%	39.68%	N/A	311.53%	N/A	1.51%	-6.58%	48.38%

Table 3.2.3.2. Number of traps reported fished by state in the Georges Bank Stock Unit.

Year	Rhode Island	Massachusetts	New Hampshire	Total
1982	*NA*	27,560	*NA*	27,560
1983	*NA*	28,922	*NA*	28,922
1984	*NA*	30,651	*NA*	30,651
1985	*NA*	34,950	*NA*	34,950
1986	*NA*	36,950	*NA*	36,950
1987	*NA*	39,674	*NA*	39,674
1988	*NA*	39,732	*NA*	39,732
1989	*NA*	39,163	*NA*	39,163
1990	*NA*	35,891	*NA*	35,891
1991	*NA*	36,784	*NA*	36,784
1992	*NA*	38,745	*NA*	38,745
1993	*NA*	43,041	*NA*	43,041
1994	*NA*	47,894	*NA*	47,894
1995	*NA*	44,480	*NA*	44,480
1996	*NA*	42,008	*NA*	42,008
1997	*NA*	40,974	*NA*	40,974
1998	*NA*	45,327	*NA*	45,327
1999	*NA*	47,941	*NA*	47,941
2000	*NA*	41,464	*NA*	41,464
2001	*NA*	40,899	*NA*	40,899
2002	*NA*	47,387	*NA*	47,387
2003	*NA*	42,834	*NA*	42,834
2004	*NA*	43,922	*NA*	43,922
2005	*NA*	40,694	*NA*	40,694
2006	*NA*	40,175	*NA*	40,175
2007	*NA*	42,307	NA	42,307

Table 3.2.4.1. Southern New England landings in metric tons by state from 1981 to 2007. 2007 landings are preliminary estimates.

Year	CT	MA	NMFS	NY	RI	Total
1981	366	432	324	379	340	1,842
1982	399	527	457	508	788	2,680
1983	750	608	414	548	1,468	3,788
1984	815	678	530	593	1,638	4,254
1985	626	579	600	563	1,592	3,961
1986	569	590	627	643	1,955	4,383
1987	713	578	722	520	1,924	4,457
1988	872	628	771	713	1,768	4,752
1989	942	674	997	1,064	2,263	5,940
1990	1,200	909	1,066	1,549	2,895	7,620
1991	1,213	934	799	1,419	2,721	7,086
1992	1,149	813	573	1,203	2,496	6,233
1993	987	868	445	1,210	2,499	6,008
1994	974	979	271	1,794	2,757	6,774
1995	1,153	980	301	3,018	2,553	8,004
1996	1,310	976	313	4,268	2,521	9,388
1997	1,573	1,168	406	4,027	2,761	9,935
1998	1,684	1,098	338	3,582	2,675	9,376
1999	1,177	989	447	2,927	3,473	9,013
2000	629	739	456	1,308	2,941	6,073
2001	600	748	291	931	1,896	4,465
2002	482	750	133	653	1,633	3,652
2003	303	465	113	429	1,244	2,554
2004	290	449	193	531	1,021	2,484
2005	323	507	198	556	1,018	2,601
2006	358	544	240	590	1,256	2,989
2007	247	386	345	403	1,053	2,435

1981 to 2003 mean	804	726	458	1,331	1,968	5,287
2005 to 2007 mean	309	479	261	516	1,109	2,675
3 yr. % change from mean	-61.52%	-34.02%	-43.03%	-61.19%	-43.66%	-49.41%

Table 3.2.4.2. Number of traps reported fished by state in the Southern New England Stock Unit. RI data not included in totals because data were not consistently collected over the time period.

Year	Connecticut	Massachusetts	New York	Rhode Island	Total
1981	15,815	41,395	48,295		105,505
1982	14,831	44,123	43,977		102,931
1983	19,998	46,303	59,808		126,109
1984	66,709	49,072	77,599		193,380
1985	65,262	55,954	88,332		209,548
1986	65,826	59,156	77,429		202,411
1987	70,646	63,518	76,729		210,893
1988	79,154	63,610	101,790		244,554
1989	83,915	62,700	143,320		289,935
1990	100,360	53,768	137,504		291,632
1991	101,290	59,922	155,276		316,488
1992	107,668	58,406	187,661		353,735
1993	115,224	62,615	237,117		414,956
1994	110,805	71,472	269,419		451,696
1995	119,983	71,269	252,581		443,833
1996	130,360	71,830	314,297		516,487
1997	133,770	76,717	335,860		546,347
1998	158,527	83,166	346,729		588,422
1999	162,149	83,394	332,323		577,865
2000	122,386	68,162	212,767	170,616	403,314
2001	121,501	65,225	191,853	173,133	378,579
2002	117,731	78,965	157,747	152,021	354,443
2003	85,048	63,444	101,207	133,687	249,699
2004	84,071	55,191	102,351	128,081	241,613
2005	83,946	47,779	85,817	117,610	217,542
2006	90,421	52,990	89,301	120,242	232,712
2007	81,792	50,399	81,424	130,556	213,615

Table 5.1.1.2.1. Gulf of Maine number of biological samples collected by sea and port sampling by year and NMFS statistical area.

Number of Biological Sea Samples by NMFS Statistical Area

YEAR	464	465	467	511	512	513	514	515	Total Sea
1981							3,125		3,125
1982							3,196		3,196
1983						985	3,747		4,732
1984						4,177	3,680		7,857
1985					356	331	8,499		9,186
1986				95	415	974	8,612		10,096
1987				295	488	737	7,593		9,113
1988					566	805	8,828		10,199
1989				198	374	890	8,297		9,759
1990					894	767	10,483		12,144
1991					431	3,595	9,379		13,405
1992		501			427	1,780	8,239		10,947
1993	1,029	1,820		602	1,276	1,950	6,852	861	14,390
1994	9,068	1,896			857	2,615	9,155	1,794	25,385
1995		1,793			460	3,192	9,906	1,282	16,633
1996	3,397			339	575	3,425	8,977	1,106	17,819
1997	716				524	1,930	15,450		18,620
1998				1,780	1,969	2,705	7,807		14,261
1999	1,465			1,525	4,240	5,304	10,657		23,191
2000				5,892	22,571	17,030	11,181	64	56,738
2001				7,309	23,357	20,655	8,031		59,352
2002				3,439	32,371	20,907	9,451		66,168
2003				9,987	36,906	17,374	10,872		75,139
2004				6,442	17,684	17,799	9,863		51,788
2005				6,363	20,249	19,253	7,500		53,365
2006				7,411	22,717	16,529	6,233		52,890
Total	15,675	6,010	0	51,677	189,707	165,709	215,613	5,107	649,498

Number of Biological Port Samples by NMFS Statistical Area

YEAR	464	465	467	511	512	513	514	515	Total Port
1981				200	1,791	729			2,720
1982				294	1,828	986			3,108
1983	116			379	1,015	1,395			2,905
1984	215			278	1,042	1,547			3,082
1985	468			893	921	772		466	3,520
1986				179	929	975			2,083
1987	116			818	827	1,159			2,920
1988				390	1,593	817			2,800
1989				767	698	1,614			3,079
1990				100	1,332	1,189			2,621
1991				589	1,422	1,160		100	3,271
1992				496	1,738	1,660			3,894
1993				500	1,364	1,210			3,074
1994				338	1,470	1,565			3,373
1995				668	1,267	1,165			3,100
1996				280	2,024	870			3,174
1997				683	2,552	1,379			4,614
1998				310	2,600	1,570			4,480
1999				690	2,422	1,529			4,641
2000				239	2,470	1,614			4,323
2001				319	2,081	1,894			4,294
2002				560	2,798	1,563			4,921
2003				847	2,190	1,937		54	5,028
2004				1,420	2,090	1,354		27	4,891
2005	1,064			1,030	2,885	3,456		100	8,535
2006	300	200		799	2,693	4,115	13	4,359	12,479
Total	2,279	200	0	14,066	46,042	39,224	13	5,106	106,930

Table 5.1.1.2.2. Georges Bank number of biological samples collected by sea and port sampling by year and NMFS statistical area.

Number of Biological Sea Samples by NMFS Statistical Area

YEAR	521	522	525	526	541	542	543	561	562	Total Sea
1981	512									512
1982	984									984
1983	1478									1,478
1984	824									824
1985	1713									1,713
1986	1461									1,461
1987	1513									1,513
1988	1723									1,723
1989	1770									1,770
1990	2434									2,434
1991	2122		154	355						2,631
1992	3263									3,263
1993	2847		333							3,180
1994	3001		652					5		3,658
1995	3307	208	1,016							4,531
1996	2843	6	3,311	31					1,063	7,254
1997	2368									2,368
1998	2096	44		1,107						3,247
1999	1812	4,545	438	269				3,446	5,891	16,401
2000	2593	46								2,639
2001	2123									2,123
2002	2532									2,532
2003	2674									2,674
2004	2677	276	8	13					580	3,554
2005	2987	464	4,248	2,347				65	1,557	11,668
2006	3236	319		3						3,558
Total	56,893	5,908	10,160	4,125	0	0	0	3,516	9,091	89,693

Number of Biological Port Samples by NMFS Statistical Area

YEAR	521	522	525	526	541	542	543	561	562	Total Port
1981										0
1982										0
1983			846							846
1984		590	2,011	164						2,765
1985		156	775	855						1,786
1986			402	981						1,383
1987			940	1,047						1,987
1988			1,020	1,496				106		2,622
1989			420	822					248	1,490
1990			243	2,069					560	2,872
1991			453	2,449						2,902
1992			546	3,705					717	4,968
1993			127	1,778					129	2,034
1994										0
1995										0
1996										0
1997	90	43								133
1998										0
1999										0
2000										0
2001										0
2002			223						108	331
2003	60		69	138					206	473
2004			46	97					146	289
2005			231	283				116	59	689
2006			2,381	2,909					6,772	12,062
Total	150	789	10,733	18,793	0	0	0	222	8,945	39,632

Table 5.1.1.2.3. Southern New England number of biological samples collected by sea and port sampling by year and NMFS statistical area.

Number of Biological Sea Samples by NMFS Statistical Area

YEAR	533	534	537	538	539	611	612	613	614	615	616	621	622	623	624	625	626	627	631	632	635	Total Sea
1981				368																		368
1982				418		1,231																1,649
1983				1,437		4,712																6,149
1984				972		3,926																4,898
1985				1,292		6,833																8,125
1986				1,614		3,347																4,961
1987				2,072		3,600																5,672
1988				2,855		6,275																9,130
1989				2,118		4,487																6,605
1990			1,675	1,443	346	5,349					3,402											12,215
1991			5,298	1,082	9,030	3,030					13,366											31,806
1992			3,180	2,104	4,317	3,779					11,879											25,259
1993			92	3,014	4,813	4,600	13	48			10,162											22,742
1994				1,537	5,254	7,230	167	7			9,734											23,929
1995				1,680	7,315	1,132	27	4			10,179	1					3					20,341
1996				1,381	6,704	2,631					12,019		1									22,736
1997			10	1,179	6,199	2,201	3	11			14,716		2									24,321
1998			735	1,953	4,845	3,807	9			3	13,109											24,461
1999				1,990	5,540	7,620	150				15,821											31,121
2000				3,271	4,997	10,217	147				18,871											37,503
2001				4,307	3,961	17,720	15				12,737											38,740
2002				2,831	3,272	11,727	307				12,364											30,501
2003				1,271	2,566	12,778	336				13,381											30,332
2004				2,337	1,927	6,399	72				9,535		3				2					20,275
2005			221	2,709	2,113	4,886	34				9,568											19,531
2006			1	2,653	2,641	4,550	60	4			9,354		5				1					19,269
Total	0	0	11,212	49,888	75,840	144,067	1,340	74	0	3	200,197	1	11	0	0	0	6	0	0	0	0	482,639

Number of Bilogical Port Samples by NMFS Statistical Area

YEAR	533	534	537	538	539	611	612	613	614	615	616	621	622	623	624	625	626	627	631	632	635	Total Port
1981																						0
1982																						0
1983			998																			998
1984			932																			932
1985			461																			461
1986			674								275						86					1,035
1987			703								663			149								1,515
1988			496								362											858
1989			348					76														424
1990			422		110						355											887
1991			560								452											1,012
1992			1,069								239											1,308
1993			138								570											708
1994								84			140			93								317
1995			255					125														380
1996																						0
1997			784								418											1,202
1998			364																			364
1999			454								321											775
2000			405																			405
2001																						0
2002			208								89											297
2003			417								110											527
2004			64					34			157											255
2005			78			1,038					235											1,351
2006			2,167			88	113	250			779											3,397
Total	0	0	11,997	0	110	1,126	113	569	0	0	5,165	0	0	242	0	0	86	0	0	0	0	19,408

Table 5.2.1.1. Sampling seasons and strata used in fishery-independent surveys.

Survey (yrs)	Seasons	Strata (N)	Annual Samples
NMFS	Spring (March-April)	Statistical Area (44)	612-831
(1981-present)	Fall (Sept-Oct)	Depth (7)	
ME	Spring (May)	Region (5)	92-115
(2000-present)	Fall (October-November)	Depth (4)	
MA			163-199
(1981-present)	Fall (September)	Depth (6)	
RI	Spring (May)	Region (3)	60-139
(1979-present)	Fall (September)	Depth (?)	
CT	Spring (Apr-Jun)	Depth (4)	102-200
(1984-present)	Fall (Sept-Oct)	Bottom Type (3)	
NJ	Spring (April and June)	Region (5)	186
(1988-present)	Fall (October)	Depth (3)	

Table 5.2.1.2.1 Abundance index data (mean catch per tow summed for 53-228 mm).
Indices represent stratified delta mean number per tow from bottom trawl surveys carried out by the Northeast Fisheries Science Center (NEFSC), Massachusetts (MA), Connecticut (CT), Rhode Island (RI), and New Jersey (NJ); geometric mean number per tow was reported for Maine (ME).

	Spring							Fall							
YEAR	GOM NMFS	GOM ME	GBK NMFS	SNE NMFS	SNE CT	SNE RI	SNE NJ	GOM NMFS	GOM ME	GOM MA	GBK NMFS	SNE NMFS	SNE CT	SNE RI	SNE NJ
Females															
1981						1.69				7.17				3.86	
1982	0.26		0.24	0.30		0.38		0.28		6.25	0.68	0.57		0.65	
1983	0.26		0.14	0.13		1.11		0.72		11.94	0.59	0.42		1.08	
1984	0.34		0.06	0.12		1.26		0.38		9.09	0.58	1.00	15.40	2.22	
1985	1.89		0.09	1.61	9.23	0.45		1.10		17.58	0.54	0.72	7.52	2.21	
1986	0.55		0.27	0.15	4.59	1.48		1.14		5.01	0.80	0.67	11.49	1.43	
1987	0.85		0.12	0.54	6.88	0.95		0.41		1.23	0.55	0.31	13.34	4.03	
1988	0.62		0.82	0.13	3.50	0.55		0.84		5.07	0.73	0.51	6.59	6.03	
1989	0.27		0.18	0.11	7.35	1.95	0.97	1.12		8.19	0.65	0.84	8.37	5.06	0.60
1990	0.67		0.22	0.45	15.34	2.74	1.00	0.95		32.63	0.65	0.93	14.94	1.96	0.23
1991	0.72		0.22	0.28	19.45	7.11	0.92	1.11		12.80	0.83	0.49	24.67	3.20	0.51
1992	0.67		0.26	0.26	26.38	0.99	0.79	0.54		9.90	0.83	0.94	21.78	4.13	0.31
1993	0.39		0.31	0.39	21.11	8.87	0.65	0.70		4.03	0.66	0.47	34.58	5.09	0.88
1994	0.68		0.07	0.18	9.43	1.04	0.58	1.98		22.59	0.57	0.12	31.33	5.12	0.91
1995	0.88		0.10	0.02	25.37	1.36	1.38	1.22		19.29	0.62	0.63	24.52	5.68	0.54
1996	1.34		0.33	0.20	28.59	3.10	0.54	2.78		20.87	0.54	1.72	25.35	6.97	0.51
1997	1.85		0.08	0.89	45.62	4.63	0.74	1.85		7.02	0.75	1.40	70.84	8.84	0.41
1998	1.74		0.12	0.44	63.90	2.97	1.02	1.78		11.44	0.72	0.79	22.35	3.15	0.33
1999	1.08		0.55	0.93	65.33	2.72	0.46	3.17		10.34	0.79	0.38	23.96	1.74	1.00
2000	2.66		0.21	0.51	40.54	1.90	1.02	2.08	43.12	14.53	0.72	0.84	16.73	1.60	0.06
2001	1.63	14.37	0.48	0.18	26.19	4.14	0.50	1.47	30.35	1.89	1.08	0.48	11.45	2.93	0.10
2002	2.50	28.82	0.37	1.02	16.52	5.03	0.31	2.65	37.26	12.56	1.49	0.24	3.08	0.48	0.13
2003	2.49	19.91	0.67	0.15	6.13	0.63	0.13	1.19	42.70	0.73	0.85	0.28	9.89	1.49	0.03
2004	2.59	10.80	0.26	0.27	4.25	2.06	0.09	2.06	30.53	1.54	0.89	0.27	5.58	1.60	0.23
2005	1.46	33.27	0.35	0.10	4.17	0.97	0.07	0.82	56.80	5.10	0.87	0.25	3.55	4.81	0.46
2006	2.61	35.09	0.49	0.42	3.41	3.78	0.21	1.30	43.83	13.08	1.03	0.25	1.99	4.25	0.00
2007	2.22	33.65	0.45	0.25	5.42	0.55	0.63	0.82	45.39	2.68	1.12	0.38	1.37	3.10	0.24

Table 5.2.1.2.1 Continued Abundance index data (mean catch per tow summed for 53-228 mm).

	Spring							Fall							
YEAR	GOM NMFS	GOM ME	GBK NMFS	SNE NMFS	SNE CT	SNE RI	SNE NJ	GOM NMFS	GOM ME	GOM MA	GBK NMFS	SNE NMFS	SNE CT	SNE RI	SNE NJ
Males															
1981						2.01				7.28				5.26	
1982	0.25		0.39	0.36		0.30		0.22		5.97	0.5245	0.44		1.22	
1983	0.24		0.19	0.18		1.30		0.72		11.54	0.6882	0.45		1.00	
1984	0.18		0.06	0.07		1.73		0.20		11.27	0.5659	0.97	14.05	3.99	
1985	0.35		0.17	1.18	8.17	0.55		0.91		16.52	0.4516	0.63	6.23	2.59	
1986	0.29		0.36	0.34	4.31	1.41		1.18		7.35	0.7728	0.65	14.18	3.56	
1987	0.60		0.11	0.71	6.82	1.33		0.55		1.37	0.7162	0.31	14.51	3.97	
1988	0.68		0.90	0.09	3.31	0.46		0.63		7.09	0.7871	0.32	7.68	9.15	
1989	0.06		0.30	0.14	7.95	1.67	0.87	1.32		9.05	0.8546	0.72	10.81	8.00	1.10
1990	0.26		0.34	0.35	13.10	3.13	0.58	1.39		36.36	0.5424	0.65	16.99	3.06	0.19
1991	0.59		0.16	0.19	25.33	8.84	1.08	1.10		15.69	0.4998	0.52	29.46	6.53	0.78
1992	0.42		0.18	0.15	22.49	1.23	0.91	0.73		11.71	0.4921	0.82	29.59	5.26	0.28
1993	0.21		0.51	0.49	15.89	9.71	0.46	0.80		5.45	0.3376	0.40	37.67	6.49	0.81
1994	0.18		0.10	0.17	8.70	1.26	0.47	2.23		22.85	0.5192	0.19	37.09	10.98	0.56
1995	1.25		0.04	0.01	22.54	1.97	1.45	1.89		19.32	0.2772	0.50	35.39	9.24	0.13
1996	0.72		0.22	0.21	23.53	2.63	0.42	2.93		22.33	0.378	1.51	21.77	11.76	1.04
1997	1.54		0.02	0.98	40.75	4.99	0.75	1.59		8.36	0.75	1.38	69.78	14.09	0.59
1998	0.87		0.07	0.41	56.99	3.24	1.16	1.71		11.84	0.5477	0.97	29.76	6.31	0.53
1999	0.64		0.31	1.39	49.37	2.82	1.02	2.11		13.92	0.6295	0.47	34.80	4.64	1.64
2000	3.12		0.32	0.69	32.97	2.75	0.82	2.20	45.13	15.37	0.6594	0.56	22.44	2.39	0.19
2001	1.04	14.41	0.41	0.42	28.59	3.86	0.39	1.08	32.69	2.18	0.4641	0.35	15.61	5.68	0.45
2002	1.19	33.45	0.22	0.72	15.94	4.65	0.26	1.60	37.25	13.52	0.9478	0.20	5.64	1.33	0.28
2003	1.04	22.02	0.34	0.37	7.39	0.42	0.17	0.76	45.37	0.89	0.5988	0.21	9.19	2.26	0.07
2004	0.78	13.52	0.17	0.13	4.65	1.51	0.05	2.57	30.26	2.66	0.2908	0.27	7.06	2.16	0.25
2005	0.67	35.32	0.11	0.10	3.72	1.17	0.23	0.79	58.32	5.78	0.2387	0.27	4.06	6.98	0.70
2006	1.62	39.69	0.14	0.20	2.93	4.52	0.16	1.14	47.27	12.74	0.2285	0.40	2.43	4.37	0.13
2007	1.27	36.68	0.14	0.21	4.43	0.80	0.68	0.69	43.93	3.11	0.2889	0.33	1.82	4.70	0.33

Table 5.2.2.2.1 Number of trap hauls by NMFS statistical area 511, 512, 513, and 514 per ventless trap survey year for the Gulf of Maine.

Year	511	512	513	514
2006	701	718	656	583
2007	894	2,104	1,398	2,835

Table 5.2.2.2.2 Number of trap hauls by NMFS statistical area 538, 539, and 611 per ventless trap survey year for Southern New England.

Year	538	539	611
2006	572	852	324
2007	1,889	848	804

Table 6.3.1. Stock-specific configurations of the University of Maine assessment model.

Item	Gulf of Maine (GOM)	Georges Bank (GBK)	Southern New England (SNE)
Separate sexes?	Yes	No (female and male data pooled)	Yes
Survey catchability	Closed form MLE for lognormal surveys (median unbiased)		
Recruitment	Independent (not autocorrelated)		
Type NLL for survey trends	Lognormal (not robust) with internally estimated variance		
Priors	None		
Initial size compostion	Equilibrium size composition at mortality rates similar to initial estimates		
Type landings data	Catch number by quarter and sex	Catch weight by quarter and sex	Catch number by quarter and sex
Survey standard deviation for NLL	Variance of log scale survey time series used intially; variance specified in final runs and tuned to approximately variance from residuals		
Effective samples sizes	Initially set at number of trips (comm) or number of positive tows (surveys) for all years and sexes, tuned in final runs by sex and data source	Educated guesses for initial runs; tuned in in preliminary runs	Initially set at number of trips (comm) or number of positive tows (surveys) for all years and sexes, tuned in final runs by sex and data source
Lik. wts on survey trend, survey & comm length, comm landings data	Weights =1 in basecase runs		
Model years	Calendar years with quarterly time steps, 1982-2007	Calendar year quarterly time steps, 1982-2008 (spring survey and aver. landings for 2008; 2008 estimates not presented)	Calendar years with quarterly time steps, 1982-2007
Length bins	35 bins each 5 mm starting at 53 mm CL (i.e. 53-57, 58-62, …, 223 mm CL)		
Proportion of annual recruitment during each season	Winter 0%; Spring 0%; Summer 66.15%; Winter 33.85%		
Surveys used (1982-2007 unless noted); trend and length data	NEFSC fall; MA 514 fall; ME fall (2000-2007 only); males and females separated but assigned to the same survey	NEFSC fall; NEFSC spring (1982-2008); males and females combined	NEFSC fall; CT fall; RI fall; males and females separated but assigned to same survey
Survey selectivity	Ascending logistic curve for fall NEFSC, descending logistic curves for fall ME and MA, ME parameters initially estimated then specified	Separate ascending logistic curves for fall and spring	Ascending logistic curve for fall NEFSC, dome-shaped but largely descending logistic curves for fall CT and RI
Maturity parameters	ASMFC (2006), p. 9 (area specific)		
Commercial selectivity - legal sizes	Catch weighted estimates for each state or subregion, same for both sexes		
Commercial selectivity - gear	Catch weighted estimates for each state or subregion, same for both sexes		
Commercial selectivity - conservation (v-notching and eggers)	Sea sample data for all years and quarters; varies with size, assumed same in each quarter and over time	Sea sample data for well sampled years and quarters; varies with size, assumed same in each quarter and over time	Sea sample data for all years and quarters; varies with size, two time periods for pre/post RI vnotch program: 1982-1999 and 2000-2007
Commercial selectivity - "other"	Selectivity due to other sources did not substantially improve model fit and parameters were difficulat to estimate. Therefore, selectivity due to other sources was assumed to be one for all size groups.		
Length -weight parameters	Area- and sex specific from Estrella and McKiernan (1989)		
Commercial length data	All years and quarters	Well sampled years and quarters only.	All years and quarters
Natural mortality rate	M=0.0375 per quarter (0.15 per year), assumed constant all size groups, quarters and years for all base runs		
Sex ratio at recruitment	Estimated, assumed constant over time	NA	Estimated, assumed constant over time
Spawning season	Summer		
Plus groups for size data NLL	Static binning: Comm (6-14), NEFSC (1-27), ME (1-14), MA (1-14)	Dynamic binning	Static binning: Comm (6-14), NEFSC (1-20), CT (1-10), RI (1-9)
Growth transition matrix	Calculated with an individual-based simulation model and best estimates for stock- and sex- specfic biological parameters, current fishery regulations and size and sex- molt duration probability distributions from the Life History model.		
Annual wt for R constraints	None	0 for 1982-2006; 1 for 2007; 5 for 2008	None

Table 6.3.2. Gulf of Maine landings in numbers from 1982 to 2007 by NMFS statistical area.
Note: 2007 landings are preliminary.

Year	464	465	467	511	512	513	514	515	Total
1982	1,323			1,593,574	8,464,045	7,860,565	7,400,130	70,163	25,389,800
1983	17,571			1,463,434	8,451,964	7,653,991	8,470,656	121,851	26,179,467
1984	51,056	200		1,381,874	6,800,692	7,957,692	7,846,572	138,268	24,176,354
1985	72,373	1,856		1,338,419	7,099,121	8,242,553	8,911,739	140,354	25,806,415
1986	51,910			1,459,828	6,379,234	8,285,057	8,251,955	109,996	24,537,980
1987	32,170			1,751,684	6,653,070	8,316,246	8,280,322	564	25,034,056
1988	15,509			1,829,968	7,572,698	8,992,826	8,309,420	236	26,720,657
1989	14,111			1,841,888	8,042,933	9,407,549	10,358,492	69	29,665,042
1990				1,732,236	9,615,021	11,233,752	10,156,343	296,993	33,034,345
1991				1,777,252	10,259,917	12,683,802	9,581,741	335,063	34,637,775
1992				1,573,084	8,502,431	11,837,872	8,620,479	22,926	30,556,792
1993	81,662	36,202		1,734,414	10,787,605	11,251,794	8,015,630	90,708	31,998,015
1994	185,353	817		2,159,850	15,145,112	13,154,145	9,373,299	35,535	40,054,111
1995	111,750	29,335		2,012,346	16,303,070	10,696,872	9,269,220	232,439	38,655,032
1996	106,887	28,058		2,641,751	14,542,239	11,308,787	8,876,666	222,665	37,727,053
1997	83,603	21,948		3,123,545	19,868,668	13,678,757	8,323,837	175,435	45,275,793
1998	69,643	18,282		3,207,876	20,381,091	12,798,352	6,794,486	166,401	43,436,131
1999	55,146	14,478		2,926,630	22,884,471	15,218,400	8,758,553	157,987	50,015,665
2000	89,971	23,616		3,616,229	24,886,870	14,819,861	8,901,654	194,492	52,532,693
2001	119,260	31,307		5,172,680	20,524,472	11,856,559	6,337,950	213,969	44,256,197
2002	112,145	29,439		5,539,285	27,107,186	16,353,284	7,023,307	210,315	56,374,961
2003	338,965	84,586		5,072,219	25,082,142	11,600,316	5,956,514	96,061	48,230,803
2004	251,554	52,278		5,734,556	30,852,426	18,160,937	5,935,134	192,517	61,179,402
2005	177,906	49,724		6,683,364	30,498,621	15,313,661	5,392,509	216,719	58,332,504
2006	180,603	87,337		8,031,161	32,099,159	15,083,126	5,917,930	334,203	61,733,519
2007	131,065	80,998	194,664	7,892,102	25,637,235	14,503,672	5,495,331	200,991	54,136,058
1982 to 2003 median	72,373	23,616	*NA*	1,835,928	10,523,761	11,280,291	8,397,247	139,311	33,836,060
2005 to 2007 median	177,906	80,998	194,664	7,892,102	30,498,621	15,083,126	5,495,331	216,719	58,332,504
3 yr. % change from median	145.8%	243.0%	*NA*	329.9%	189.8%	33.7%	-34.6%	55.6%	72.4%

Table 6.3.3. Southern New England landings in numbers from 1982 to 2007 by NMFS statistical area.
Note2007 landings are preliminary.

Year	533	534	537	538	539	611	612	613	614	615	616	621	622	623	624	625	626	627	631	632	635	Total
1982			649,569	726,375	779,539	1,150,408	336,919	8,106	1,585	73	438,598	53,087	61,199	28		162	34,113			31		4,239,792
1983			987,295	821,925	1,761,611	2,056,236	344,758	6,132	2,765	863	149,347	36,009	63,963			150	48,852			1,977		6,281,883
1984			1,337,108	714,665	1,865,315	2,256,202	484,796	27,823	4,337	223	263,523	81,522	78,884			1,178	72,722	267	10	1,806		7,190,381
1985			1,263,351	782,426	1,863,747	1,919,925	711,624	47,228	5,853	373	409,435	127,070	66,776		455	509	76,353					7,275,125
1986			1,637,853	628,555	2,103,061	2,042,292	786,789	74,156	2,493	267	494,546	89,704	84,189			736	80,147			18,599		8,043,387
1987			1,696,852	786,912	2,063,199	2,076,201	1,078,934	125,282	2,521		340,875	79,586	46,836	2,760		348	81,069					8,381,375
1988		1,895	1,486,381	860,825	1,977,462	2,755,209	1,216,097	125,937	2,630		230,765	65,841	58,039			240	55,761					8,837,082
1989		4,493	1,658,778	886,247	2,552,823	3,139,526	1,482,160	195,853	2,370	12,282	323,061	64,580	100,487			239	42,578			1,372		10,466,849
1990			3,318,683	392,628	3,264,063	3,471,125	1,414,737	343,893	3,216	84,761	646,521	83,064	50,028	59,061		977	54,050		11			13,186,818
1991			2,955,577	370,229	3,040,838	3,533,140	1,100,273	422,507	6,227	244	412,552	72,592	122,500	12,729		1,963	14,266		298			12,065,935
1992			2,137,129	275,776	2,820,055	3,607,971	807,998	276,652	9,118	51	660,447	47,868	46,011	75,055		361	16,434		171	25		10,781,122
1993			2,152,606	377,540	2,744,902	3,326,521	687,114	470,479	7,304	140	464,658	56,284	48,689	58,866		546	56,851		55			10,452,555
1994			1,700,588	511,890	4,096,915	4,723,352	289,212	119,702	3,124		367,173	15,803	58,836	94,513		258	6,308		9			11,987,683
1995			1,575,551	548,302	3,895,933	7,188,535	409,246	309,956	3,474		216,406	30,074	45,917	93,360		339	8,230					14,325,323
1996			1,599,976	557,215	3,857,861	9,668,138	362,455	399,852	2,944	384	181,131	34,996	75,001	149,072		2,409	7,918					16,899,352
1997			1,918,343	550,992	4,283,925	9,751,552	460,348	422,080	4,211	796	198,480	22,027	103,679	181,297		662	17,894				28	17,916,314
1998	7		1,705,174	637,558	4,154,218	8,815,207	493,324	660,507	4,771	947	191,350	24,603	57,747	91,289		680	12,076				368	16,849,826
1999			1,914,260	504,001	5,319,842	7,004,614	545,593	469,557	5,685		245,893	52,241	58,836	170,268		834	14,897					16,306,521
2000			1,599,467	205,980	4,540,827	3,192,142	515,271	311,063	5,854		207,648	30,696	60,536	165,947		860	14,799				2,211	10,853,301
2001			1,304,983	321,286	2,938,541	2,525,104	309,607	250,061	3,618		131,283	35,240	37,411	97,168		1,051	9,190				744	7,965,287
2002	50		1,194,937	400,676	2,463,359	1,894,194	120,921	191,114	1,468	463	105,999	7,938	15,264	68,158		719	4,503					6,469,763
2003	67		1,484,210	195,701	661,470	1,185,938	125,334	179,296	1,526	1,672	265,173	8,838	15,654	75,312		493	3,072					4,203,756
2004	2,694		1,015,634	231,086	670,141	1,260,692	241,409	92,583	2,534	47,832	284,374	14,346	45,953	52,308		332	4,566					3,966,484
2005	487		974,058	257,983	837,719	1,401,044	232,725	62,748	1,602	11,470	245,818	21,562	16,298	69,051		236	3,167			2		4,135,970
2006	2,517		1,043,139	240,237	1,146,532	1,489,336	269,143	81,326	5,009	13,199	291,287	21,869	29,419	102,085		467	7,882			2		4,743,449
2007	63		873,463	184,823	890,756	1,024,045	369,941	50,756	5,396	1,547	240,306	30,691	38,919	104,755		1,072	7,313			51		3,823,897
1982 to 2003 median	50	3,194	1,618,915	549,647	2,782,479	3,165,834	504,298	222,957	3,345	384	264,348	50,055	58,836	83,301	455	604	17,164	267	33	1,589	556	10,459,702
2005 to 2007 median	487	*NA*	974,058	240,237	890,756	1,401,044	269,143	62,748	5,009	11,470	245,818	21,869	29,419	102,085	*NA*	467	7,313	*NA*	*NA*	2	*NA*	4,135,970
3 yr. % change from median	874.0%	*NA*	-39.8%	-56.3%	-68.0%	-55.7%	-46.6%	-71.9%	49.7%	2887.0%	-7.0%	-56.3%	-50.0%	22.6%	*NA*	-22.7%	-57.4%	*NA*	*NA*	-99.9%	*NA*	-60.5%

Table 6.3.4. Georges Bank landings in numbers from 1982 to 2007 by NMFS statistical area.
Note: 2007 landings are preliminary.
* From 1981 through 1984 Area 561 was 523, and 562 was 524

Year	521	522	525	526	541	542	543	561(523)	562(524)	Total
1982	91,964	17,306	849,436	510,359				25,893	115,097	1,610,055
1983	113,509	42,797	1,068,840	204,591				77,353	99,865	1,606,955
1984	114,266	47,614	624,492	609,347				30,663	115,085	1,541,467
1985	151,644	53,547	529,073	666,252	6,724			29,121	299,865	1,736,226
1986	181,930	57,396	380,897	721,608				54,794	240,096	1,636,721
1987	175,274	54,492	285,915	775,424				9,277	361,719	1,662,101
1988	187,926	45,566	399,072	834,753				35,741	316,854	1,819,912
1989	214,573	34,080	224,982	789,534				11,941	373,372	1,648,482
1990	349,688	91,548	441,440	894,210				9,065	28,786	1,814,737
1991	454,223	90,894	527,827	886,578				16,099	69,448	2,045,069
1992	450,278	34,365	566,067	954,055				61,413	176,321	2,242,499
1993	613,244	29,778	674,769	701,096				3,408	164,888	2,187,183
1994	544,472	33,483	481,230	486,595				105,857	235,651	1,887,288
1995	641,673	62,635	354,971	358,646				75,889	137,692	1,631,506
1996	527,476	65,455	388,149	274,107				77,636	181,638	1,514,461
1997	542,779	112,967	457,147	332,653		251		68,586	211,405	1,725,788
1998	512,871	133,422	438,366	273,465				77,827	260,944	1,696,895
1999	432,288	150,138	421,424	355,551				63,054	213,063	1,635,518
2000	473,484	146,703	526,548	255,345				90,190	110,461	1,602,731
2001	374,192	225,839	319,408	335,709		26		162,665	477,533	1,895,372
2002	464,643	247,631	289,829	376,546			277	101,105	389,331	1,869,362
2003	444,064	261,027	350,089	219,123	105,339			72,827	568,307	2,020,776
2004	530,971	84,267	209,110	288,523	101,972			114,665	256,528	1,586,036
2005	520,786	107,933	284,832	274,414	6,557			125,667	596,101	1,916,290
2006	564,816	108,243	279,385	252,504				234,286	404,061	1,843,295
2007	598,710	110,130	243,580	420,922	810			101,215	332,945	1,808,312
1982 to 2003 median	438,176	60,016	439,903	498,477	56,032	139	277	62,234	212,234	1,711,342
2005 to 2007 median	564,816	108,243	279,385	274,414	3,684	*NA*	*NA*	125,667	404,061	1,843,295
3 yr. % change from median	28.9%	80.4%	-36.5%	-44.9%	-93.4%	*NA*	*NA*	101.9%	90.4%	7.7%

Table 6.3.5. Years and quarters with commercial length samples from all combined Statistical Areas on GBK (i.e. Statistical Areas 521&526, 522&525, and 561&562) by sex. Commercial length data from other seasons and quarters were not used in modeling.

Season	Sex	Year
Winter	Female	2006
Spring	Female	1990
Spring	Female	1992
Spring	Female	2006
Summer	Female	1989
Summer	Female	1990
Summer	Female	1992
Summer	Female	2002
Summer	Female	2003
Summer	Female	2005
Summer	Female	2006
Fall	Female	1999
Fall	Female	2005
Fall	Female	2006
Winter	Male	2006
Spring	Male	1990
Spring	Male	1992
Spring	Male	2006
Summer	Male	1989
Summer	Male	1990
Summer	Male	1992
Summer	Male	2002
Summer	Male	2003
Summer	Male	2005
Summer	Male	2006
Fall	Male	1999
Fall	Male	2005
Fall	Male	2006

Table 6.3.6. Minimum and maximum legal size (CfL, mm) weighted by landings, used for legal selectivity

	Minimun size			Maximum size
Year	**GOM**	**GBK**	**SNE**	**GOM**
1981	81	81	81	128
1982	81	81	81	128
1983	81	81	81	128
1984	81	81	81	128
1985	81	81	81	128
1986	81	81	81	128
1987	81	81	81	128
1988	82	82	82	128
1989	83	83	83	128
1990	83	83	83	128
1991	83	83	83	128
1992	83	83	83	128
1993	83	83	83	128
1994	83	83	83	128
1995	83	83	83	128
1996	83	83	83	128
1997	83	83	83	128
1998	83	83	83	128
1999	83	83	83	128
2000	83	83	83	128
2001	83	83	83	128
2002	83	84	83	128
2003	83	85	85	128
2004	83	86	85	128
2005	83	87	85	128
2006	83	87	86	128
2007	83	88	86	128

Table 7.1.1.1. CSM lobster population estimates and data for sexes combined in GOM.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits	Landings Fraction Female	Recruits Fraction Female	Post-recruits Fraction Female	Stock Fraction Female
1982	33.50	12.78	46.28		0.91		0.15	1.06	26.00	0.56	0.72	0.51	0.57	0.41	0.53
1983	38.35	16.00	54.35		0.66		0.15	0.81	24.67	0.45	0.71	0.50	0.50	0.56	0.52
1984	24.13	24.11	48.24	49.62	0.85	0.80	0.15	1.00	25.96	0.54	0.50	0.52	0.58	0.54	0.56
1985	35.96	17.72	53.68	52.09	0.71	0.74	0.15	0.86	25.56	0.48	0.67	0.51	0.44	0.61	0.49
1986	30.54	22.74	53.28	51.73	0.66	0.74	0.15	0.81	24.09	0.45	0.57	0.49	0.54	0.48	0.51
1987	21.53	23.80	45.33	50.76	0.91	0.76	0.15	1.06	25.64	0.57	0.47	0.48	0.45	0.53	0.49
1988	38.42	15.57	53.99	50.86	0.83	0.80	0.15	0.98	28.62	0.53	0.71	0.50	0.51	0.52	0.51
1989	45.56	20.26	65.82	55.05	0.75	0.83	0.15	0.90	32.64	0.50	0.69	0.51	0.46	0.52	0.48
1990	44.41	26.71	71.12	63.64	0.75	0.78	0.15	0.90	35.40	0.50	0.62	0.48	0.45	0.44	0.44
1991	33.17	28.73	61.91	66.28	0.77	0.76	0.15	0.92	31.20	0.50	0.54	0.49	0.57	0.40	0.49
1992	37.78	24.66	62.43	65.16	0.75	0.75	0.15	0.90	30.92	0.50	0.61	0.49	0.47	0.50	0.48
1993	47.18	25.42	72.60	65.65	0.78	0.77	0.15	0.93	37.12	0.51	0.65	0.48	0.48	0.47	0.48
1994	69.03	28.43	97.46	77.50	0.59	0.71	0.15	0.74	40.64	0.42	0.71	0.50	0.49	0.48	0.49
1995	45.04	46.54	91.58	87.21	0.54	0.64	0.15	0.69	36.10	0.39	0.49	0.50	0.48	0.48	0.48
1996	60.80	45.63	106.43	98.49	0.56	0.56	0.15	0.71	43.10	0.40	0.57	0.49	0.52	0.46	0.49
1997	51.69	52.03	103.72	100.58	0.62	0.58	0.15	0.77	45.03	0.43	0.50	0.50	0.55	0.50	0.52
1998	64.16	47.92	112.07	107.41	0.58	0.59	0.15	0.73	46.55	0.42	0.57	0.53	0.60	0.55	0.58
1999	67.55	53.67	121.23	112.34	0.66	0.62	0.15	0.81	55.31	0.46	0.56	0.52	0.58	0.61	0.60
2000	65.32	53.56	118.88	117.39	0.53	0.59	0.15	0.68	45.85	0.39	0.55	0.50	0.53	0.66	0.59
2001	68.66	60.18	128.84	122.98	0.56	0.58	0.15	0.71	52.07	0.40	0.53	0.50	0.56	0.65	0.60
2002	72.17	63.06	135.23	127.65	0.45	0.51	0.15	0.60	46.17	0.34	0.53	0.51	0.48	0.68	0.58
2003	26.11	73.92	100.03	121.37	0.89	0.64	0.15	1.04	55.78	0.56	0.26	0.51	0.28	0.61	0.53
2004	92.44	35.04	127.48	120.91	0.65	0.66	0.15	0.80	57.12	0.45	0.73	0.52	0.57	0.55	0.57
2005	43.39	57.26	100.65	109.39	1.16	0.90	0.15	1.31	65.49	0.65	0.43	0.50	0.44	0.61	0.54
2006	57.32	26.83	84.15	104.09	1.25	1.02	0.15	1.40	56.94	0.68	0.68	0.51	0.47	0.62	0.52
2007	22.61	20.47	43.09	75.96							0.52		0.56	0.53	0.55
Median 82-03	44.73	27.57	71.86	71.89	0.68	0.72	0.15	0.83	35.75	0.47	0.57	0.50	0.50	0.52	0.50
Min 82-03	21.53	12.78	45.33	49.62	0.45	0.51	0.15	0.60	24.09	0.34	0.26	0.48	0.33	0.38	0.47
Max 82-03	72.17	73.92	135.23	127.65	0.91	0.83	0.15	1.06	55.78	0.57	0.72	0.53	0.59	0.64	0.58
Mean 05-07	41.11	34.86	75.96	96.48	1.21	0.96	0.15	1.36	61.21	0.66	0.55	0.49	0.43	0.60	0.53
Mean 04-06	64.38	39.71	104.09	111.46	1.02	0.86	0.15	1.17	59.85	0.59	0.61	0.51	0.49	0.60	0.54

Table 7.1.2.1. CSM lobster population estimates and data for sexes combined in GBK.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits	Landings Fraction Female	Recruits Fraction Female	Post-recruits Fraction Female	Stock Fraction Female
1982	2.41	4.17	6.58		0.33		0.15	0.48	1.73	0.26	0.37	0.47	0.63	0.70	0.67
1983	2.56	4.07	6.63		0.26		0.15	0.41	1.41	0.21	0.39	0.53	0.55	0.75	0.67
1984	2.69	4.40	7.10	6.77	0.30	0.30	0.15	0.45	1.72	0.24	0.38	0.48	0.67	0.72	0.70
1985	2.38	4.52	6.90	6.88	0.29	0.28	0.15	0.44	1.62	0.23	0.34	0.50	0.69	0.78	0.74
1986	3.50	4.45	7.95	7.31	0.25	0.28	0.15	0.40	1.63	0.21	0.44	0.49	0.59	0.83	0.72
1987	3.96	5.33	9.29	8.04	0.24	0.26	0.15	0.39	1.84	0.20	0.43	0.45	0.51	0.79	0.67
1988	2.28	6.29	8.57	8.60	0.22	0.23	0.15	0.37	1.57	0.18	0.27	0.47	0.63	0.73	0.70
1989	2.44	5.93	8.37	8.74	0.25	0.24	0.15	0.40	1.75	0.21	0.29	0.48	0.51	0.76	0.68
1990	3.41	5.59	9.00	8.65	0.29	0.25	0.15	0.44	2.11	0.23	0.38	0.44	0.71	0.74	0.73
1991	2.62	5.81	8.43	8.60	0.30	0.28	0.15	0.45	2.06	0.24	0.31	0.41	0.58	0.83	0.75
1992	4.30	5.36	9.66	9.03	0.29	0.29	0.15	0.44	2.27	0.23	0.45	0.46	0.67	0.86	0.78
1993	2.69	6.23	8.92	9.01	0.29	0.29	0.15	0.44	2.07	0.23	0.30	0.47	0.58	0.88	0.79
1994	1.53	5.78	7.31	8.63	0.27	0.28	0.15	0.42	1.60	0.22	0.21	0.56	0.42	0.90	0.80
1995	2.40	4.81	7.21	7.81	0.28	0.28	0.15	0.43	1.64	0.23	0.33	0.58	0.61	0.87	0.78
1996	2.03	4.70	6.74	7.09	0.30	0.28	0.15	0.45	1.64	0.24	0.30	0.59	0.56	0.85	0.76
1997	4.25	4.28	8.53	7.49	0.24	0.27	0.15	0.39	1.68	0.20	0.50	0.57	0.68	0.82	0.75
1998	3.26	5.78	9.04	8.10	0.22	0.25	0.15	0.37	1.69	0.19	0.36	0.56	0.65	0.80	0.75
1999	1.96	6.22	8.18	8.58	0.25	0.24	0.15	0.40	1.68	0.21	0.24	0.47	0.60	0.80	0.75
2000	4.72	5.49	10.22	9.15	0.20	0.22	0.15	0.35	1.73	0.17	0.46	0.47	0.73	0.83	0.78
2001	3.37	7.20	10.57	9.66	0.21	0.22	0.15	0.36	1.88	0.18	0.32	0.46	0.66	0.85	0.79
2002	3.37	7.36	10.73	10.50	0.22	0.21	0.15	0.37	1.98	0.18	0.31	0.54	0.70	0.87	0.81
2003	4.26	7.41	11.66	10.98	0.17	0.20	0.15	0.32	1.67	0.14	0.36	0.62	0.75	0.88	0.83
2004	1.59	8.49	10.09	10.83	0.23	0.20	0.15	0.38	1.91	0.19	0.16	0.62	0.51	0.87	0.81
2005	2.03	6.92	8.95	10.24	0.24	0.21	0.15	0.39	1.78	0.20	0.23	0.66	0.80	0.86	0.85
2006	0.67	6.07	6.74	8.59	0.35	0.27	0.15	0.50	1.86	0.28	0.10	0.64	0.38	0.90	0.85
2007	1.82	4.09	5.91	7.20							0.31		0.57	0.93	0.82
Median 82-03	2.69	5.54	8.48	8.60	0.26	0.27	0.15	0.41	1.70	0.21	0.35	0.50	0.50	0.52	0.50
Min 82-03	1.53	4.07	6.58	6.77	0.17	0.20	0.15	0.32	1.41	0.14	0.21	0.48	0.33	0.38	0.47
Max 82-03	4.72	7.41	11.66	10.98	0.33	0.30	0.15	0.48	2.27	0.26	0.50	0.53	0.59	0.64	0.58
Mean 05-07	1.51	5.69	7.20	8.68	0.29	0.24	0.15	0.44	1.82	0.24	0.21	0.49	0.43	0.60	0.53
Mean 04-06	1.43	7.16	8.59	9.88	0.27	0.23	0.15	0.42	1.85	0.22	0.16	0.64	0.56	0.88	0.84

Table 7.1.3.1. CSM lobster population estimates and data for sexes combined in SNE.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits	Landings Fraction Female	Recruits Fraction Female	Post-recruits Fraction Female	Stock Fraction Female
1982															
1983															
1984	7.45	4.22	11.68	11.68	0.91		0.15	1.06	6.60	0.57	0.64	0.58	0.59	0.73	0.64
1985	7.60	4.01	11.61	11.64	0.90		0.15	1.05	6.50	0.56	0.65	0.62	0.62	0.73	0.66
1986	9.69	4.05	13.73	12.34	0.81	0.87	0.15	0.96	7.18	0.52	0.71	0.59	0.62	0.73	0.65
1987	7.12	5.25	12.37	12.57	0.95	0.89	0.15	1.10	7.17	0.58	0.58	0.59	0.62	0.72	0.66
1988	9.86	4.08	13.94	13.35	1.06	0.94	0.15	1.21	8.62	0.62	0.71	0.60	0.56	0.79	0.62
1989	14.81	4.13	18.94	15.08	0.89	0.97	0.15	1.04	10.50	0.55	0.78	0.60	0.65	0.67	0.66
1990	12.37	6.69	19.05	17.31	1.07	1.01	0.15	1.22	11.81	0.62	0.65	0.60	0.58	0.74	0.64
1991	10.33	5.61	15.94	17.98	0.96	0.97	0.15	1.11	9.26	0.58	0.65	0.54	0.54	0.70	0.60
1992	11.98	5.25	17.23	17.41	0.98	1.00	0.15	1.13	10.14	0.59	0.70	0.55	0.62	0.69	0.64
1993	13.42	5.56	18.98	17.38	0.91	0.95	0.15	1.06	10.67	0.56	0.71	0.55	0.59	0.79	0.65
1994	12.47	6.57	19.04	18.41	1.41	1.10	0.15	1.56	13.66	0.72	0.65	0.54	0.43	0.80	0.56
1995	18.90	3.96	22.86	20.29	1.24	1.18	0.15	1.39	15.36	0.67	0.83	0.63	0.67	0.60	0.66
1996	20.76	5.69	26.45	22.78	1.15	1.26	0.15	1.30	17.11	0.65	0.78	0.60	0.61	0.74	0.64
1997	17.31	7.17	24.48	24.60	1.29	1.22	0.15	1.44	16.79	0.69	0.71	0.67	0.64	0.71	0.66
1998	15.90	5.81	21.71	24.21	1.49	1.31	0.15	1.64	15.96	0.74	0.73	0.58	0.59	0.64	0.60
1999	11.51	4.21	15.72	20.64	1.40	1.39	0.15	1.55	11.25	0.72	0.73	0.47	0.47	0.71	0.54
2000	9.07	3.31	12.38	16.61	1.18	1.36	0.15	1.33	8.12	0.66	0.73	0.54	0.55	0.72	0.60
2001	6.38	3.29	9.66	12.59	1.34	1.31	0.15	1.49	6.77	0.70	0.66	0.52	0.51	0.74	0.59
2002	5.03	2.19	7.22	9.76	1.06	1.19	0.15	1.21	4.46	0.62	0.70	0.43	0.44	0.78	0.54
2003	4.32	2.15	6.46	7.78	0.92	1.11	0.15	1.07	3.66	0.57	0.67	0.42	0.45	0.75	0.55
2004	4.35	2.22	6.58	6.75	1.01	1.00	0.15	1.16	3.96	0.60	0.66	0.48	0.51	0.74	0.59
2005	4.00	2.05	6.06	6.37	1.40	1.11	0.15	1.55	4.33	0.72	0.66	0.46	0.46	0.78	0.57
2006	4.42	1.62	6.04	6.22	1.04	1.15	0.15	1.19	3.69	0.61	0.73	0.47	0.48	0.71	0.54
2007	4.44	1.85	6.28	6.13							0.71		0.53	0.68	0.58
Median 82-03	10.92	4.22	15.83	16.96	1.06	1.10	0.15	1.21	9.70	0.62	0.70	0.58	0.59	0.73	0.64
Min 82-03	4.32	2.15	6.46	7.78	0.81	0.87	0.15	0.96	3.66	0.52	0.58	0.42	0.43	0.60	0.54
Max 82-03	20.76	7.17	26.45	24.60	1.49	1.39	0.15	1.64	17.11	0.74	0.83	0.67	0.67	0.80	0.66
Mean 05-07	4.29	1.84	6.13	6.24	1.22	1.13	0.15	1.37	4.01	0.66	0.70	0.46	0.49	0.73	0.56
Mean 04-06	4.26	1.97	6.22	6.45	1.15	1.09	0.15	1.30	3.99	0.64	0.68	0.47	0.49	0.74	0.57

Table 7.2.1.1. Log scales standard deviations (SD) used (assumed) and calculated from goodness of fit (GOF) for landings and survey trend data in the basecase model for GOM.

Data type	GOF	Used
Landings data		
Fall Female	0.03	0.05
Fall Male	0.12	0.10
Spring Female	0.01	0.05
Spring Male	0.02	0.05
Summer Female	0.14	0.10
Summer Male	0.14	0.10
Winter Female	0.01	0.05
Winter Male	0.04	0.05
Survey trend data		
NEFSC Fall Female	0.50	0.50
NEFSC Fall Male	0.57	0.56
ME DMR Fall Female	0.22	0.23
ME DMR Fall Male	0.23	0.23
MA DMF Fall Female	1.10	1.00
MA DMF Fall Male	1.03	1.00

Table 7.2.1.2 Effective sample sizes for length data used (assumed) and calculated from goodness of fit (GOF) for GOM.

Data type	Used	GOF mean	GOF median	N years data
Landings data				
Commercial Fall Female	73	96	73	26
Commercial Fall Male	119	604	119	26
Commercial Spring Female	132	298	131	26
Commercial Spring Male	96	409	95	26
Commercial Summer Female	39	60	42	26
Commercial Summer Male	99	284	100	26
Commercial Winter Female	47	64	49	26
Commercial Winter Male	56	87	57	26
Survey data				
NEFSC Fall Female	35	55	35	26
NEFSC Fall Male	38	45	38	26
ME DMR Fall Female	67	372	199	8
ME DMR Fall Male	67	69	67	8
MA DMF Fall Female	32	159	108	26
MA DMF Fall Male	32	33	32	26

Table 7.2.1.3. Basecase model estimates for Gulf of Maine. R = Recruitment and SSB = Spawning Stock Biomass in metric tons (mt).

Year	Female R	Male R	Female Reference Abundance	Male Reference Abundance	Female Effective Exploitation	Male Effective Exploitation	Both sexes Effective Exploitation	Female SSB (mt)
1982	32,629,100	31,521,400	24,157,600	20,678,900	0.51	0.56	0.54	5,938
1983	9,802,140	9,469,380	22,662,900	18,854,300	0.51	0.48	0.50	4,117
1984	27,166,700	26,244,500	26,525,600	24,873,900	0.47	0.50	0.48	3,671
1985	9,355,020	9,037,440	26,193,100	23,986,500	0.56	0.57	0.56	4,424
1986	36,969,300	35,714,300	23,764,100	22,350,300	0.53	0.52	0.53	3,700
1987	20,175,100	19,490,200	23,210,000	22,084,400	0.48	0.51	0.50	3,417
1988	27,207,200	26,283,600	29,466,200	27,726,900	0.44	0.46	0.45	3,885
1989	28,557,200	27,587,800	33,177,200	31,083,000	0.47	0.49	0.48	4,750
1990	25,167,700	24,313,300	33,592,200	31,515,600	0.48	0.48	0.48	4,807
1991	35,615,100	34,406,000	34,890,400	33,373,200	0.46	0.52	0.49	4,764
1992	29,443,100	28,443,500	36,429,600	33,167,300	0.51	0.50	0.51	5,357
1993	27,707,600	26,767,000	38,126,900	36,337,300	0.46	0.45	0.46	5,002
1994	37,000,900	35,744,800	40,203,200	38,787,900	0.49	0.49	0.49	5,746
1995	36,420,600	35,184,200	39,011,800	37,623,800	0.49	0.51	0.50	5,901
1996	35,957,900	34,737,200	41,626,400	39,431,300	0.48	0.45	0.46	5,659
1997	58,673,700	56,681,800	45,190,900	44,303,400	0.46	0.50	0.48	6,191
1998	20,070,800	19,389,500	49,912,700	46,374,000	0.48	0.47	0.47	6,872
1999	57,232,700	55,289,800	55,537,600	53,675,200	0.49	0.45	0.47	6,970
2000	29,567,200	28,563,500	51,393,500	51,152,200	0.52	0.51	0.52	7,205
2001	57,095,300	55,157,000	51,468,400	50,877,000	0.45	0.43	0.44	6,913
2002	42,734,000	41,283,300	54,608,400	54,162,200	0.46	0.53	0.50	7,691
2003	53,184,500	51,379,000	59,266,000	54,330,300	0.41	0.43	0.42	8,493
2004	32,556,700	31,451,500	65,067,200	60,199,200	0.46	0.44	0.45	9,333
2005	46,168,500	44,601,200	64,314,200	61,998,400	0.46	0.49	0.47	9,576
2006	42,229,000	40,795,400	59,312,300	55,308,300	0.50	0.52	0.51	9,440
2007	59,839,800	57,808,400	55,450,900	51,845,900	0.52	0.43	0.47	8,710
Min	9,355,020	9,037,440	22,662,900	18,854,300	0.41	0.43	0.42	3,417
Max	59,839,800	57,808,400	65,067,200	61,998,400	0.56	0.57	0.56	9,576
Mean	35,327,956	34,128,655	41,713,819	39,465,412	0.48	0.49	0.49	6,097
Median	34,122,100	32,963,700	39,607,500	38,205,850	0.48	0.49	0.48	5,823

Table 7.2.1.4 Summary of basecase and alternate model runs for GOM.
Goodness of fit is measured by negative log-likelihood (NLL) statistics for 1 July. Biomass in metric tons.

NLL, estimate or reference point	Basecase	Alternate catch at length (CAL)	Track fall survey trends	Track fall survey trends w/ alt CAL	Track spring trends	Spring & fall trends
Goodness of fit (NLL) - smaller is better						
Female landings	**0.0**	1.4	447.0	434.6	236.8	8.5
Male landings	0.0	**-11.3**	361.3	336.9	98.1	-1.8
Female commercial lengths	0.0	**-26.1**	85.0	37.3	16.9	20.3
Male commercial lengths	0.0	7.6	49.8	11.7	0.4	**-26.8**
NEFSC female fall lengths	0.0	**-11.9**	---	---	---	-11.0
NEFSC male fall lengths	0.0	20.3	29.5	9.8	3.3	**-21.6**
NEFSC female fall trends	0.0	**-1.6**	---	---	---	0.2
NEFSC male fall trends	0.0	-0.2	-8.8	**-8.9**	1.6	0.1
ME DMR female fall lengths	0.0	-5.5	**-1742.0**	-1734.3	-1384.8	-1331.1
ME DMR male fall lengths	0.0	8.7	---	---	---	**-1823.2**
ME DMR female fall trends	**0.0**	0.4	11.7	10.8	15.8	22.8
ME DMR male fall trends	**0.0**	0.5	---	---	---	32.2
MA DMR female fall lengths	0.0	**-11.2**	17.6	14.4	453.3	456.8
MA DMR male fall lengths	**0.0**	26.0	32.5	39.8	336.0	336.7
MA DMR female fall trends	0.0	-0.1	-7.1	-6.8	**-36.9**	-31.4
MA DMR male fall trends	0.0	0.0	-7.3	-7.0	**-35.7**	-29.6
Recruit variability	**0.0**	2.2	22.6	23.2	9.0	7.1
Total unweighted NLL	0.0	-0.9	1366.6	1236.1	1788.6	**-2391.9**
Converged?	Yes	Yes	Yes	Yes	Yes	Yes
Status variables (means 2005-2007)						
Female effective exploitation	0.49	0.49	***0.51***	0.51	0.37	0.48
Male effective exploitation	0.48	0.47	0.51	***0.53***	0.39	0.48
Both sexes effective exploitation	0.48	0.48	0.51	***0.52***	0.38	0.48
Female reference abundance	59,692,500	61,854,900	**43,129,400**	43,934,900	93,511,800	58,750,500
Male reference abundance	56,384,200	58,102,400	**38,687,000**	40,471,000	86,155,400	55,482,100
Both sexes reference abundance	116,077,000	119,957,000	**81,816,400**	84,405,900	179,667,000	114,233,000
Female spawning biomass	12,370	12,886	**8,862**	8,896	15,573	12,220
Male spawning biomass	10,290	10,734	**6,753**	7,435	13,414	9,984
Both sexes spawning biomass	22,660	23,620	**15,615**	16,332	28,987	22,205
Trend Reference points (median 1982-2003)						
Female effective exploitation	0.48	0.47	0.49	**0.50**	0.48	0.48
Male effective exploitation	0.49	0.49	0.49	**0.50**	0.49	**0.50**
Both sexes effective exploitation	0.49	0.48	**0.50**	**0.50**	0.48	0.49
Female reference abundance	37,278,250	36,703,750	41,647,450	44,037,100	**32,556,000**	35,886,950
Male reference abundance	34,855,250	34,268,300	37,770,950	40,119,450	**29,197,600**	34,430,350
Both sexes reference abundance	72,030,500	70,971,600	78,958,700	83,821,650	**61,753,600**	70,306,800
Female spawning biomass	7,158	6,927	7,544	7,880	**5,997**	6,656
Male spawning biomass	5,619	5,685	6,483	6,727	**4,775**	5,451
Both sexes spawning biomass	12,564	12,612	14,124	14,663	**10,828**	11,958
Status relative to trend reference points						
Female effective exploitation	**ABOVE**	**ABOVE**	**ABOVE**	**ABOVE**	BELOW	AT MEDIAN
Male effective exploitation	BELOW	BELOW	**ABOVE**	**ABOVE**	BELOW	BELOW
Both sexes effective exploitation	BELOW	AT MEDIAN	**ABOVE**	**ABOVE**	BELOW	BELOW
Female reference abundance	ABOVE	ABOVE	ABOVE	**BELOW**	ABOVE	ABOVE
Male reference abundance	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE
Both sexes reference abundance	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE
Female spawning biomass	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE
Male spawning biomass	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE
Both sexes spawning biomass	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE	ABOVE
Per recruit reference points						
Effective exploitation at F_{max}	0.34	0.34	0.34	0.34	0.34	0.34
Effective exploitation at $F_{0.1}$	0.17	0.17	0.17	0.13	**0.10**	0.17
Female effective exploitation at $F_{10\%}$	0.30	0.30	0.30	0.30	0.30	0.30
Both sexes effective exploitation at $F_{10\%}$	0.33	0.33	0.33	0.33	**0.32**	0.33
Female effective exploitation at $F_{20\%}$	0.20	0.20	0.20	0.20	0.20	0.20
Both sexes effective exploitation at $F_{20\%}$	**0.23**	**0.23**	**0.23**	0.24	**0.23**	**0.23**
Female effective exploitation at $F_{30\%}$	0.15	0.15	**0.14**	**0.14**	**0.14**	0.15
Both sexes effective exploitation at $F_{30\%}$	**0.17**	**0.17**	0.18	0.18	**0.17**	0.18
Other						
Female median recruitment	34,122,100	37,594,500	34,399,750	34,179,500	32,229,700	**30,217,600**
Male median recruitment	32,963,700	36,006,100	31,550,950	31,692,650	30,081,650	**29,409,550**
Both sexes median recruitment	67,085,750	73,600,600	65,950,700	65,872,150	62,311,400	**59,627,150**
Female mean recruitment	**35,327,956**	38,132,732	36,024,428	38,557,772	43,587,858	35,544,274
Male mean recruitment	34,128,655	36,521,639	**33,041,040**	35,752,347	40,682,785	34,593,742
Both sexes mean recruitment	69,456,573	74,654,335	**69,065,461**	74,310,123	84,270,650	70,137,992

Table 7.2.2.1 Log scales standard deviations (SD) used (assumed) and calculated from goodness of fit (GOF) for landings and survey trend data in the basecase model for GBK.

Data type	GOF	Used
Landings data		
Fall	0.19	0.15
Spring	0.16	0.15
Summer	0.2	0.15
Winter	0.17	0.15
Survey trend data		
NEFSC spring	0.66	0.67
NEFSC fall	0.46	0.4

Table 7.2.2.2 Effective sample sizes for length data used (assumed) and calculated from goodness of fit (GOF) for GBK.

Data type	Used	GOF mean	GOF median	N years data
Commercial fall	60	105.8	63	3
Commercial spring	70	70.9	67.4	3
Commercial summer	250	233.7	251.9	7
Commercial winter	30	28.8	28.8	1
NEFSC spring	25	27	23.8	26
NEFSC fall	50	55.5	51.7	26

Table 7.2.2.3. Basecase model estimates for Georges Bank. Spawning biomass is ½ of the total estimate for 1 July. Other estimates are for females and males combined.

Year	Recruitment	Reference abundance	Effective exploitation	Spawning biomass (mt)
1982	2,069,040	1,719,020	0.51	198
1983	983,981	1,706,160	0.58	195
1984	1,430,830	1,776,940	0.64	143
1985	1,322,650	1,590,990	0.63	138
1986	2,608,810	1,448,180	0.65	99
1987	194,036	1,586,240	0.57	93
1988	2,642,660	1,938,790	0.52	133
1989	938,473	1,739,180	0.52	179
1990	1,388,740	1,968,510	0.51	164
1991	993,953	1,893,800	0.53	205
1992	3,162,250	1,654,550	0.58	170
1993	580,684	1,677,740	0.6	117
1994	938,548	2,146,410	0.48	117
1995	3,298,030	1,930,910	0.49	197
1996	1,258,450	1,801,370	0.52	188
1997	279,474	2,444,130	0.41	194
1998	1,826,320	2,436,140	0.36	299
1999	2,347,350	1,962,540	0.48	351
2000	3,261,090	1,977,900	0.33	305
2001	3,704,980	2,909,700	0.3	370
2002	2,609,520	4,087,030	0.22	546
2003	2,236,410	5,304,760	0.23	858
2004	2,549,900	5,636,550	0.26	1210
2005	268,504	5,380,300	0.29	1322
2006	3,158,170	4,803,460	0.3	1233
2007	1,094,670	3,912,250	0.31	1155
Min	194,036	1,448,180	0.22	93
Max	3,704,980	5,636,550	0.65	1322
Mean	1,813,366	2,593,598	0.45	392
Median	1,628,575	1,950,665	0.5	196

Table 7.2.2.4. Summary of basecase and alternate model runs for GBK.
Goodness of fit measured by negative log-likelihood (NLL) statistics for 1 July. Other estimates are for females and males combined.

NLL, estimate or reference point	Basecase	Male growth	M=0.1	M=0.2	Fit survey trends	Fit survey lengths	Fit fall survey	Fit spring survey
Goodness of fit (NLL) - smaller is better								
Landings	0	2.4	0.2	1.4	***-4.9***	-0.4	-2	-0.8
Commercial lengths	0	***-54.1***	8.9	2	-38.5	0.2	-1.5	-0.6
Spring survey lengths	0	-35.3	-12.1	2.1	38	-0.7	31.4	***-54.8***
Spring survey trends	0	0.2	-0.4	0.1	1.8	***0.4***	0.1	-0.1
Fall survey lengths	0	27.6	4.8	***-7.8***	110.7	-0.8	0	105.1
Fall survey trends	0	-6.8	-1.5	0.1	***-7.7***	3.9	-2.8	1.5
Recruit variability	0	1.4	0.1	0.3	***-9.7***	0	-2.2	4.5
Constrain terminal recruitments	0	***-0.4***	0.4	0.2	-0.4	-0.3	***-0.4***	-0.2
Total unweighted NLL	0	***-62.5***	0.3	-0.5	84.7	2.2	20.6	54.1
Converged?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Status variables (means 2005-2007)								
Effective exploitation	0.3	0.28	0.28	0.25	0.32	***0.23***	0.31	0.25
Reference abundance	4,698,670	***4,428,910***	4,597,710	5,528,170	4,557,780	6,047,200	4,653,390	5,660,160
Spawning biomass	2,826	3,066	2,855	2,852	2,454	3,242	2,447	3,198
Trend Reference points (median 1982-2003)								
Effective exploitation	0.51	0.42	0.44	0.38	***0.38***	0.41	0.41	0.42
Reference abundance	***1,912,355***	2,220,795	2,204,305	2,464,770	2,382,185	2,316,405	2,305,105	2,288,385
Spawning biomass	236	254	231	247	274	234	241	***216***
Status relative to trend reference points								
Effective exploitation	Below	Below	Below	Below	Below	Below	Below	Below
Reference abundance	Above	***Below***	Above	Above	***Below***	Above	Above	Above
Spawning biomass	Above	Above	Above	Above	Above	Above	Above	Above
Per recruit reference points								
Effective exploitation at F_{max}	0.17	0.14	***0.1***	0.21				
Effective exploitation at $F_{0.1}$	0.08	0.08	***0.05***	0.1				
Effective exploitation at $F_{10\%}$	0.25	0.22	***0.17***	0.25	Same as basecase			
Effective exploitation at $F_{20\%}$	0.15	0.14	***0.11***	0.17				
Effective exploitation at $F_{30\%}$	0.11	0.1	***0.07***	0.12				
Other								
Median recruitment	1,628,575	***1,276,700***	1,348,800	1,805,325	1,461,510	1,630,430	1,752,015	1,726,235
Mean recruitment	1,813,366	1,597,248	***1,485,077***	2,113,914	1,668,539	1,904,373	1,765,839	1,760,490

Table 7.2.3.1. Log scales standard deviations (SD) used (assumed) and calculated from goodness of fit (GOF) for landings and survey trend data in the basecase model for SNE.

Data type	GOF	Used
Landings data		
Fall Female	0.13	0.10
Fall Male	0.04	0.05
Spring Female	0.03	0.05
Spring Male	0.04	0.05
Summer Female	0.31	0.10
Summer Male	0.24	0.10
Winter Female	0.20	0.10
Winter Male	0.10	0.09
Survey trend data		
NEFSC Fall Female	0.57	0.56
NEFSC Fall Male	0.48	0.47
CT DEP Fall Female	0.71	0.71
CT DEP Fall Male	0.72	0.71
RI DEM Fall Female	0.56	0.56
RI DEM Fall Male	0.56	0.56

Table 7.2.3.2. Effective sample sizes for length data used (assumed) and calculated from goodness of fit (GOF) for SNE.

Data type	Used	GOF mean	GOF median	N years data
Landings data				
Commercial Fall Female	60	271	61	26
Commercial Fall Male	59	110	59	26
Commercial Spring Female	102	707	102	26
Commercial Spring Male	94	391	95	26
Commercial Summer Female	18	35	19	26
Commercial Summer Male	39	87	40	26
Commercial Winter Female	75	113	75	26
Commercial Winter Male	183	790	182	26
Survey data				
NEFSC Fall Female	28	30	27	26
NEFSC Fall Male	30	44	30	26
CT DEP Fall Female	114	252	115	24
CT DEP Fall Male	147	295	146	24
RI DEM Fall Female	47	65	47	26
RI DEM Fall Male	37	42	37	26

Table 7.2.3.3. Basecase model estimates for Southern New England.
R = Recruitment and SSB = Spawning Stock Biomass in metric tons (mt).

Year	Female R	Male R	Female Reference Abundance	Male Reference Abundance	Female Effective Exploitation	Male Effective Exploitation	Both sexes Effective Exploitation	Female SSB (mt)
1982	10,176,900	7,294,160	5,957,810	5,193,700	0.35	0.46	0.40	2,359
1983	9,803,140	7,026,280	6,064,710	5,236,360	0.42	0.52	0.47	2,516
1984	6,047,240	4,334,280	7,911,860	6,690,170	0.38	0.49	0.43	3,097
1985	12,360,400	8,859,170	10,488,900	7,807,060	0.43	0.52	0.47	4,001
1986	9,061,190	6,494,490	10,953,200	7,546,250	0.41	0.53	0.46	4,212
1987	9,977,020	7,150,900	12,199,900	8,402,700	0.37	0.51	0.43	4,750
1988	14,647,400	10,498,300	13,706,500	8,836,540	0.32	0.44	0.37	5,290
1989	5,438,830	3,898,210	15,307,300	9,916,910	0.34	0.43	0.38	5,988
1990	9,600,210	6,880,820	16,754,500	11,078,800	0.37	0.45	0.40	6,294
1991	14,278,100	10,233,700	15,751,200	9,770,080	0.39	0.55	0.45	5,654
1992	14,101,000	10,106,700	14,644,700	8,708,890	0.40	0.51	0.44	5,895
1993	16,374,000	11,735,900	15,758,400	10,548,700	0.34	0.45	0.38	6,310
1994	14,765,300	10,582,800	18,740,900	12,742,200	0.36	0.48	0.41	7,388
1995	17,313,000	12,408,900	20,952,300	13,858,900	0.35	0.51	0.42	8,075
1996	13,026,000	9,336,200	22,520,500	14,057,700	0.41	0.50	0.45	8,477
1997	14,352,100	10,286,700	22,313,800	14,399,400	0.39	0.50	0.43	8,307
1998	7,855,810	5,630,550	22,069,500	13,757,000	0.40	0.50	0.44	8,159
1999	7,320,370	5,246,780	20,786,400	12,591,900	0.43	0.54	0.47	7,725
2000	4,918,560	3,525,320	17,415,300	9,827,830	0.44	0.57	0.49	6,622
2001	4,293,220	3,077,110	13,744,800	7,261,140	0.44	0.52	0.47	5,271
2002	4,718,940	3,382,240	10,725,000	5,827,630	0.49	0.51	0.49	4,054
2003	6,404,750	4,590,520	8,021,270	4,811,270	0.23	0.39	0.29	3,118
2004	3,622,930	2,596,690	8,728,940	5,131,190	0.22	0.37	0.28	3,615
2005	4,824,940	3,458,210	9,597,080	5,718,330	0.32	0.37	0.34	4,019
2006	7,611,970	5,455,780	8,950,700	5,516,960	0.30	0.42	0.34	3,629
2007	9,454,820	6,776,620	8,800,390	5,446,650	0.20	0.40	0.27	3,735
Min	3,622,930	2,596,690	5,957,810	4,811,270	0.20	0.37	0.27	2,359
Max	17,313,000	12,408,900	22,520,500	14,399,400	0.49	0.57	0.49	8,477
Mean	9,705,698	6,956,436	13,802,533	8,872,472	0.37	0.48	0.41	5,329
Median	9,527,515	6,828,720	13,725,650	8,555,795	0.37	0.50	0.43	5,280

Table 7.2.3.4. Summary of basecase and alternate model runs for SNE.
Goodness of fit is measured by negative log-likelihood (NLL) statistics for 1 July. Biomass reported in metric tons.

NLL, estimate or reference point	Basecase	Trend M - up 50%	Trend M - double
Goodness of fit (NLL) - smaller is better			
Female landings	0.0	**-30.7**	-17.0
Male landings	0.0	-8.2	**-10.0**
Female commercial lengths	0.0	**-14.5**	-5.8
Male commercial lengths	**0.0**	10.2	0.1
NEFSC female fall lengths	0.0	**-14.6**	-11.9
NEFSC male fall lengths	**0.0**	14.8	9.4
NEFSC female fall trends	**0.0**	0.5	0.4
NEFSC male fall trends	**0.0**	0.5	1.0
CT DEP female fall lengths	0.0	-15.7	**-20.7**
CT DEP male fall lengths	0.0	**-27.5**	36.7
CT DEP female fall trends	0.0	0.2	**-1.2**
CT DEP male fall trends	0.0	0.0	**-1.6**
RI DEM female fall lengths	0.0	-2.1	**-15.2**
RI DEM male fall lengths	0.0	2.3	**-4.1**
RI DEM female fall trends	0.0	**-1.0**	0.7
RI DEM male fall trends	0.0	**-1.3**	0.0
Recruit variability	0.0	**-1.3**	0.0
Total unweighted NLL	0.0	**-88.4**	-39.3
Converged?	Yes	Yes	Yes
Status variables (means 2005-2007)			
Female effective exploitation	0.27	0.23	**0.21**
Male effective exploitation	0.39	0.37	**0.33**
Both sexes effective exploitation	0.32	0.29	**0.26**
Female reference abundance	**9,116,060**	9,589,300	9,844,290
Male reference abundance	**5,560,650**	6,102,410	6,336,470
Both sexes reference abundance	**14,676,700**	15,691,700	16,180,800
Female spawning biomass	**3,869**	3,911	3,876
Male spawning biomass	**2,169**	2,313	2,313
Both sexes spawning biomass	**6,038**	6,224	6,188
Trend Reference points (median 1984-2003)			
Female effective exploitation	0.39	**0.38**	**0.38**
Male effective exploitation	0.51	0.49	**0.48**
Both sexes effective exploitation	0.44	0.43	**0.41**
Female reference abundance	**15,529,250**	15,682,600	16,018,100
Male reference abundance	9,798,955	9,894,555	**9,710,130**
Both sexes reference abundance	**25,372,700**	25,632,650	25,728,250
Female spawning biomass	**6,101**	6,200	6,348
Male spawning biomass	3,583	3,541	**3,511**
Both sexes spawning biomass	**9,783**	9,816	9,786
Status relative to trend reference points			
Female effective exploitation	BELOW	BELOW	BELOW
Male effective exploitation	BELOW	BELOW	BELOW
Both sexes effective exploitation	BELOW	BELOW	BELOW
Female reference abundance	**BELOW**	**BELOW**	**BELOW**
Male reference abundance	**BELOW**	**BELOW**	**BELOW**
Both sexes reference abundance	**BELOW**	**BELOW**	**BELOW**
Female spawning biomass	**BELOW**	**BELOW**	**BELOW**
Male spawning biomass	**BELOW**	**BELOW**	**BELOW**
Both sexes spawning biomass	**BELOW**	**BELOW**	**BELOW**
Per recruit reference points			
Effective exploitation at F_{max}	0.17	*	*
Effective exploitation at $F_{0.1}$	**0.06**	0.09	0.11
Female effective exploitation at $F_{14\%}$	0.28	*	*
Both sexes effective exploitation at $F_{14\%}$	0.33	*	*
Female effective exploitation at $F_{20\%}$	0.20	*	*
Both sexes effective exploitation at $F_{20\%}$	0.24	*	*
Female effective exploitation at $F_{30\%}$	**0.12**	0.20	*
Both sexes effective exploitation at $F_{30\%}$	**0.16**	0.25	*
Other			
Female median recruitment	9,527,515	**9,326,690**	10,827,700
Male median recruitment	6,828,720	**6,552,535**	7,433,175
Both sexes median recruitment	16,356,200	**15,879,250**	18,260,850
Female mean recruitment	**9,705,698**	10,584,800	11,303,740
Male mean recruitment	**6,956,436**	7,436,432	7,759,976
Both sexes mean recruitment	**16,662,141**	18,021,222	19,063,709

* occurs at F > 3

Table 7.4.1.1. Retrospective statistic Mohn's rho calculated using terminal years 2001-2007 from the CSM where N is reference abundance and mu is effective exploitation rate.

Measure	GOM (MA DMF)	GOM (NEFSC)	GBK	SNE(CT)	SNE(RI)	SNE(NEFSC)
R female	-0.29	-0.40	-0.33	0.03	0.69	-0.15
R male	-0.11	-0.37	0.08	-0.18	0.32	-0.29
PR female	-0.15	-0.42	-0.36	0.01	1.08	-0.14
PR rmale	-0.08	-0.35	-0.08	-0.09	0.81	-0.15
N female	-0.24	-0.44	-0.36	0.03	0.75	-0.14
N male	-0.11	-0.37	0.09	-0.19	0.48	-0.26
mu female	0.03	0.38	0.46	0.00	-0.13	0.11
mu male	0.02	0.26	0.09	0.02	-0.08	0.05

Table 7.4.2.1 Retrospective statistic Mohn's rho calculated using terminal years 2001-2007 from the University of Maine model. * Model exhibited problems converging in some or all retrospective runs.

Stock unit	Run	Effective exploitation	Reference abundance
GOM	Basecase	0.85	-0.91
GOM	Remove ME DMR	1.05	-0.93
GOM	Alternate CAL	0.56	-0.49
GOM	Offshore surveys only	0.53	-0.53
GOM	Inshore surveys only	0.95	-0.96
GOM	Area 514	0.01	0.03
GOM	Area 3 *	3.02	-1.13
GBK	Basecase	-0.12	0.84
GBK	Fit spring survey	0.85	-0.75
SNE	Basecase	-0.75	0.62
SNE	Trend in M (up to 0.3)	0.24	-0.27
SNE	Area 611 *	-0.97	0.47

Table 7.5.2.1.1 Gulf of Maine mortality indicators categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

	1. Exploitation Rate					
Description	Landings numbers by area/ Number > 77 mm from survey (sexes combined)					
Survey	NEFSC		ME		MA	
Season	Fall	Spring	Fall	Spring	Fall	Spring
1981		-			0.26	0.21
1982	1.00	0.75			0.19	0.59
1983	0.29	0.82			0.15	1.00
1984	0.58	0.68			0.17	0.67
1985	0.19	0.14			0.15	0.55
1986	0.23	0.40			0.27	0.49
1987	0.34	0.32			1.00	0.58
1988	0.31	0.54			0.56	0.64
1989	0.27	1.00			0.33	0.44
1990	0.21	0.49			0.12	0.28
1991	0.25	0.41			0.16	0.54
1992	0.49	0.54			0.28	0.29
1993	0.33	0.84			0.53	0.29
1994	0.18	0.64			0.12	0.33
1995	0.20	0.38			0.17	0.40
1996	0.13	0.31			0.16	0.48
1997	0.30	0.31			0.22	0.33
1998	0.25	0.34			0.27	0.30
1999	0.18	0.64	-		0.22	0.41
2000	0.28	0.32	0.76	-	0.18	0.28
2001	0.38	0.31	0.94	1.00	0.48	0.29
2002	0.22	0.28	0.98	0.53	0.26	0.38
2003	0.34	0.25	0.70	0.78	0.83	0.50
2004	0.26	0.32	1.00	0.94	0.84	0.33
2005	0.67	0.45	0.67	0.47	0.47	0.17
2006	0.48	0.36	0.98	0.51	0.24	0.22
2007	0.63	0.37	0.89	0.65	0.54	0.82
2005-07 Avg.	0.59	0.39	0.85	0.54	0.42	0.40
25th	0.23	0.31	0.70	0.50	0.17	0.29
Median	0.29	0.38	0.89	0.59	0.26	0.40
75th	0.37	0.59	0.98	0.82	0.47	0.54

	2. Median Length					
Description	Median length Greater Than 77 mm (sexes combined)					
Survey	NEFSC		ME		MA	
Season	Fall	Spring	Fall	Spring	Fall	Spring
1981					83	81
1982	89	94			84	81
1983	88	103			82	84
1984	93	114			84	80
1985	91	119			83	80
1986	88	111			83	80
1987	89	96			85	80
1988	85	96			82	80
1989	89	106			81	80
1990	85	104			82	80
1991	89	93			82	81
1992	87	93			84	81
1993	90	94			82	81
1994	86	104			81	80
1995	91	85			81	81
1996	86	100			81	81
1997	92	92			81	80
1998	87	96			81	80
1999	90	95			81	81
2000	88	92	84		81	81
2001	92	105	84	81	82	80
2002	96	98	84	81	82	80
2003	99	106	85	81	83	80
2004	92	107	86	81	80	81
2005	94	104	84	81	81	81
2006	95	97	84	81	81	80
2007	92	104	84	81	82	81
2005-07 Avg.	94	102	84	81	81	81
25th	88.0	94.3	84.0	81.0	81.0	80.0
Median	89.5	99.0	84.0	81.0	82.0	80.0
75th	92.0	104.8	84.3	81.0	83.0	81.0

	3. Proportion of the Exploitable Stock Comprised of Recruits (surveys)					
Description	Sexes combined (see 5 & 6 below for abundances)					
Survey	NEFSC		ME		MA	
Season	Fall	Spring	Fall	Spring	Fall	Spring
1981					0.67	0.71
1982	0.47	0.31			0.53	0.77
1983	0.41	0.30			0.68	0.74
1984	0.31	0.20			0.56	0.76
1985	0.34	0.03			0.67	0.87
1986	0.40	0.14			0.61	0.76
1987	0.28	0.31			0.66	0.77
1988	0.52	0.39			0.63	0.77
1989	0.50	0.00			0.70	0.84
1990	0.55	0.23			0.74	0.85
1991	0.45	0.35			0.68	0.79
1992	0.54	0.32			0.70	0.83
1993	0.35	0.25			0.80	0.81
1994	0.49	0.08			0.77	0.88
1995	0.36	0.54			0.77	0.83
1996	0.51	0.23			0.80	0.91
1997	0.49	0.44			0.80	0.86
1998	0.48	0.40			0.86	0.89
1999	0.42	0.45			0.79	0.84
2000	0.51	0.59	0.61		0.79	0.80
2001	0.41	0.27	0.63	0.79	0.66	0.86
2002	0.24	0.29	0.63	0.86	0.80	0.85
2003	0.12	0.22	0.58	0.79	0.54	0.87
2004	0.36	0.12	0.50	0.79	0.82	0.75
2005	0.28	0.10	0.58	0.78	0.75	0.82
2006	0.35	0.41	0.60	0.81	0.81	0.89
2007	0.29	0.33	0.60	0.82	0.75	0.73
2005-07 Avg.	0.30	0.28	0.59	0.80	0.77	0.81
25th	0.34	0.21	0.58	0.79	0.67	0.77
Median	0.41	0.29	0.60	0.79	0.74	0.83
75th	0.49	0.38	0.62	0.81	0.80	0.86

Table 7.5.2.1.2. Gulf of Maine abundance indicators categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

	4. Spawning Stock Abundance Index						5. Full Recruit Abundance (survey)						6.Recruit Abundance (survey)					
Description	Mean weight per tow of mature females						Abundance adjusted for Minimun Legal Size (sexes Combined)						Recruits 10mm below Minimum Legal Size					
Survey	NEFSC		ME		MA		NEFSC		ME		MA		NEFSC		ME		MA	
Season	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
1981					335	255					2.16	2.19					4.40	5.40
1982	35	119			445	99	0.20	0.32			3.42	0.72	0.17	0.14			3.82	2.43
1983	150	257			466	40	0.71	0.30			3.76	0.57	0.50	0.13			8.08	1.66
1984	170	361			369	79	0.33	0.37			3.88	0.63	0.15	0.10			4.85	1.94
1985	424	2880			560	36	1.02	2.08			4.49	0.65	0.54	0.05			9.19	4.39
1986	156	563			132	42	0.86	0.67			2.50	0.84	0.57	0.11			3.97	2.68
1987	67	517			136	110	0.61	0.77			0.61	0.69	0.24	0.34			1.21	2.26
1988	167	244			67	44	0.57	0.50			1.24	0.65	0.62	0.32			2.12	2.15
1989	260	257			180	104	0.75	0.33			1.68	0.79	0.75	0.00			3.92	4.03
1990	197	558			564	113	0.89	0.67			4.67	1.01	1.10	0.20			13.32	5.72
1991	198	445			147	101	0.97	0.79			3.26	0.70	0.81	0.42			7.01	2.55
1992	131	384			218	107	0.41	0.56			1.83	0.85	0.49	0.26			4.20	4.02
1993	198	251			59	137	0.79	0.42			0.70	1.09	0.42	0.14			2.79	4.53
1994	383	723			350	120	1.63	0.79			3.32	0.76	1.57	0.06			11.23	5.51
1995	396	295			201	117	1.63	0.78			2.45	0.77	0.90	0.93			8.40	3.90
1996	634	923			239	76	2.07	1.37			2.30	0.32	2.16	0.41			9.06	3.10
1997	492	974			84	77	1.20	1.48			1.44	0.71	1.15	1.18			5.79	4.37
1998	356	1143			125	132	1.42	1.36			0.92	0.54	1.32	0.91			5.59	4.52
1999	1122	785			183	210	2.36	0.79			1.90	0.68	1.74	0.64			7.28	3.69
2000	419	1028	3701		336	170	1.44	1.49	14.22		2.18	1.11	1.53	2.19	22.69		8.07	4.58
2001	497	1262	2009	500	147	230	1.07	1.71	9.83	2.31	0.76	0.63	0.75	0.63	16.94	8.57	1.47	3.75
2002	1802	1905	4006	877	160	136	2.72	2.35	12.57	2.90	1.16	0.52	0.84	0.95	20.98	17.20	4.69	3.04
2003	949	2141	4309	993	150	56	1.63	2.51	16.65	3.44	0.51	0.29	0.23	0.70	22.59	13.14	0.60	1.98
2004	661	2476	3779	527	82	205	2.24	2.76	16.18	2.32	0.28	0.78	1.27	0.39	16.39	8.96	1.25	2.30
2005	394	1368	4390	1626	191	463	0.92	1.87	21.09	6.53	0.63	1.09	0.35	0.20	29.67	23.61	1.89	5.01
2006	681	1583	3144	957	133	313	1.32	1.92	14.85	5.33	1.06	0.64	0.70	1.33	22.35	22.19	4.37	5.10
2007	395	1566	3253	806	150	99	0.88	1.84	14.13	4.27	0.48	0.32	0.35	0.89	21.03	19.01	1.43	0.84
2005-07 Avg.	490	1506	3596	1130	158	292	1.04	1.87	16.69	5.38	0.72	0.68	0.47	0.81	24.35	21.60	2.57	3.65
25th	177	367	3226	666	135	78	0.76	0.59	13.74	2.61	0.84	0.63	0.44	0.14	19.97	11.05	2.46	2.36
Median	388	754	3740	877	180	110	1.00	0.79	14.54	3.44	1.83	0.70	0.72	0.37	21.69	17.20	4.40	3.75
75th	496	1341	4082	975	335	153	1.58	1.80	16.30	4.80	2.88	0.82	1.14	0.85	22.62	20.60	7.68	4.52

Table 7.5.2.1.2. Continued. Gulf of Maine abundance indicators categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

Description	7. Sex ratio (Full recruits): Proportion Females from Survey Full Recruits Adjusted for Minimum Legal Size						8. Sex ratio (recruits): Proportion Females from Survey Recruits 10 mm Below Minimum Legal Size						9. Recruitment Indices: Index of Young of Year by Dive Survey			
Survey	NEFSC		ME		MA		NEFSC		ME		MA		468 Beaver Harbor, NB	513 Mount Desert, ME	514 Mid-Coast ME	514 Beverly, MA
Season	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Fall	Fall	Fall
1981					0.45	0.43					0.49	0.45				
1982	0.37	0.44			0.54	0.46	0.59	0.71			0.53	0.41				
1983	0.53	0.64			0.46	0.34	0.53	0.29			0.52	0.44				
1984	0.67	0.74			0.38	0.39	0.71	0.49			0.42	0.34				
1985	0.63	0.85			0.51	0.23	0.51	0.52			0.46	0.39				
1986	0.42	0.72			0.24	0.34	0.54	0.49			0.44	0.30				
1987	0.41	0.68			0.60	0.57	0.40	0.46			0.44	0.40				
1988	0.63	0.53			0.25	0.31	0.61	0.37			0.59	0.35				
1989	0.47	0.81			0.34	0.47	0.44				0.39	0.43			1.64	
1990	0.39	0.83			0.43	0.45	0.42	0.44			0.49	0.41			0.79	
1991	0.40	0.61			0.18	0.39	0.64	0.35			0.46	0.40	0.74		1.53	
1992	0.44	0.66			0.41	0.46	0.41	0.57			0.51	0.36	1.05		1.31	
1993	0.50	0.74			0.34	0.40	0.46	0.45			0.39	0.41	0.67		0.44	
1994	0.48	0.83			0.40	0.31	0.47	0.32			0.47	0.51	1.84		1.59	
1995	0.38	0.52			0.32	0.24	0.34	0.31			0.47	0.41	0.55	0.00	0.66	0.54
1996	0.50	0.72			0.33	0.52	0.47	0.60			0.48	0.48	0.14	0.05	0.47	0.00
1997	0.58	0.67			0.13	0.33	0.58	0.43			0.48	0.35	0.22	0.05	0.46	0.17
1998	0.43	0.83			0.47	0.57	0.56	0.46			0.65	0.39	0.36	0.00	0.13	0.03
1999	0.67	0.75			0.32	0.42	0.57	0.53			0.42	0.49	2.51	0.04	0.65	0.36
2000	0.59	0.67	0.69		0.47	0.42	0.42	0.36	0.58		0.45	0.43	0.38	0.04	0.13	0.19
2001	0.65	0.73	0.69	0.82	0.49	0.64	0.54	0.36	0.61	0.79	0.45	0.37	1.21	0.05	2.08	0.32
2002	0.72	0.78	0.72	0.89	0.51	0.50	0.53	0.51	0.57	0.84	0.49	0.40	0.86	0.04	1.38	0.79
2003	0.67	0.80	0.65	0.84	0.47	0.47	0.31	0.53	0.55	0.77	0.40	0.29	2.18	0.28	1.75	0.67
2004	0.43	0.82	0.57	0.82	0.51	0.55	0.51	0.58	0.48	0.80	0.30	0.42	2.00	0.21	1.75	1.13
2005	0.56	0.72	0.67	0.80	0.55	0.60	0.44	0.44	0.55	0.80	0.39	0.53	8.33	0.73	1.77	0.66
2006	0.62	0.79	0.66	0.82	0.29	0.81	0.37	0.48	0.59	0.83	0.55	0.38	2.74	0.88	0.84	0.25
2007	0.56	0.78	0.66	0.84	0.49	0.51	0.56	0.51	0.58	0.83	0.35	0.51	4.17	0.97	2.01	1.15
2005-07 Avg.	0.58	0.76	0.66	0.82	0.44	0.64	0.46	0.48	0.58	0.82	0.43	0.47	5.08	0.86	1.54	0.69
25th													0.55	0.04	0.56	0.19
Median	0.53	0.74	0.66	0.82	0.44	0.45	0.51	0.47	0.58	0.81	0.46	0.41	1.05	0.05	1.31	0.36
75th													2.18	0.28	1.70	0.67

Table 7.5.2.1.3. Gulf of Maine fishery performance indicators categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

	10. Effort	11. Landings	12. Median Length (mm)	13. Gross CPUE	14. Set Over Days		15. Price per Pound		16. Revenue		17. Revenue per Trap	
Description	Traps	Pounds	Commercial Catch	Pounds per trap	Average Soak Time of Traps		Un-adjusted	Adjusted to Unprocessed Fish CPI	Un-adjusted	Adjusted to Unprocessed Fish CPI	Un-adjusted	Adjusted to Unprocessed Fish CPI
Survey	ME, NH, MA				ME	MA						
1981		32,578,274	88.5		3.0		$ 2.19	$ 5.95	$ 71,376,318	$ 193,849,777		
1982	2,390,415	32,339,298	89.1	13.5	3.3		$ 2.31	$ 5.60	$ 74,644,183	$ 181,236,077	$ 31	$ 76
1983	2,599,642	33,221,334	88.9	12.8	3.4		$ 2.42	$ 5.58	$ 80,408,123	$ 185,228,580	$ 31	$ 71
1984	2,450,165	30,417,633	88.7	12.4	3.5		$ 2.69	$ 5.80	$ 81,834,767	$ 176,304,183	$ 33	$ 72
1985	2,079,758	32,094,306	88.3	15.4	3.7		$ 2.49	$ 5.27	$ 79,902,535	$ 169,287,396	$ 38	$ 81
1986	1,926,713	30,459,295	88.0	15.8	4.0		$ 2.62	$ 5.09	$ 79,761,794	$ 155,053,352	$ 41	$ 80
1987	2,265,169	30,758,952	87.7	13.6	3.6		$ 3.09	$ 5.37	$ 95,192,407	$ 165,090,832	$ 42	$ 73
1988	2,409,689	32,398,809	87.6	13.4	3.8		$ 2.99	$ 4.87	$ 96,725,009	$ 157,934,313	$ 40	$ 66
1989	2,397,299	36,833,842	88.4	15.4	4.1		$ 2.80	$ 4.76	$ 103,155,806	$ 175,271,027	$ 43	$ 73
1990	2,545,997	42,426,758	89.3	16.7	4.0		$ 2.48	$ 4.09	$ 105,250,300	$ 173,605,794	$ 41	$ 68
1991	2,444,791	44,567,363	89.2	18.2	3.8		$ 2.59	$ 4.21	$ 115,437,045	$ 187,479,026	$ 47	$ 77
1992	2,434,821	39,106,096	89.2	16.1	4.3		$ 2.90	$ 4.52	$ 113,602,824	$ 176,699,331	$ 47	$ 73
1993	2,223,031	41,451,620	89.5	18.6	4.5		$ 2.77	$ 4.29	$ 114,616,663	$ 177,820,613	$ 52	$ 80
1994	2,821,722	52,149,637	89.8	18.5	3.8	3.2	$ 2.96	$ 4.46	$ 154,486,865	$ 232,400,315	$ 55	$ 82
1995	3,026,325	50,622,356	89.9	16.7	3.4	3.2	$ 3.06	$ 4.36	$ 155,130,422	$ 220,524,980	$ 51	$ 73
1996	2,908,608	48,771,077	89.5	16.8	4.5	3.5	$ 3.39	$ 4.96	$ 165,129,183	$ 241,671,884	$ 57	$ 83
1997	3,037,165	58,694,430	89.5	19.3	4.6	3.6	$ 3.29	$ 4.48	$ 193,034,303	$ 263,159,623	$ 64	$ 87
1998	3,258,704	56,809,806	89.8	17.4	4.5	3.7	$ 3.19	$ 4.22	$ 180,942,509	$ 239,808,085	$ 56	$ 74
1999	3,462,022	65,928,353	90.3	19.0	4.8	3.5	$ 3.70	$ 4.70	$ 243,649,659	$ 309,890,714	$ 70	$ 90
2000	3,202,873	70,100,333	90.8	21.9	4.8	3.6	$ 3.61	$ 4.43	$ 253,388,246	$ 310,563,686	$ 79	$ 97
2001	3,388,850	58,415,620	90.3	17.2	5.1	3.8	$ 3.50	$ 4.46	$ 204,729,303	$ 260,525,549	$ 60	$ 77
2002	3,515,850	74,515,727	90.4	21.2	5.0	3.7	$ 3.54	$ 4.49	$ 263,575,053	$ 334,707,233	$ 75	$ 95
2003	3,623,493	64,218,001	90.5	17.7	5.2	3.9	$ 3.96	$ 4.92	$ 253,990,883	$ 315,765,419	$ 70	$ 87
2004	3,626,817	81,617,573	90.5	22.5	4.8	3.9	$ 4.16	$ 4.89	$ 339,165,291	$ 399,172,723	$ 94	$ 110
2005	3,642,248	77,289,030	90.3	21.2	5.4	4.1	$ 4.73	$ 5.16	$ 365,649,377	$ 398,830,497	$ 100	$ 110
2006	3,643,185	82,224,975	90.5	22.6	5.1	4.1	$ 4.27	$ 4.36	$ 350,843,650	$ 358,824,087	$ 96	$ 98
2007	3,621,820	72,091,492	90.5	19.9	5.2	4.1	$ 4.76	$ 4.76	$ 342,966,352	$ 342,966,352	$ 95	$ 95
2005-07 Avg.	3,635,751	77,201,832	90.4	21.2	5.2	4.1	$ 4.59	$ 4.76	$ 353,153,126	$ 366,873,646	$ 97	$ 101
25th	2,415,972	32,899,804	88.8	15.5	3.8	3.6	$ 2.65	$ 4.44	$ 95,958,708	$ 176,501,757	$ 42	$ 73
Median	2,865,165	49,696,717	89.5	17.3	4.4	3.7	$ 3.08	$ 4.73	$ 154,808,644	$ 226,462,647	$ 53	$ 80
75th	3,462,022	65,928,353	90.3	19.3	4.8	3.9	$ 3.61	$ 4.96	$ 253,388,246	$ 310,563,686	$ 70	$ 90

Table 7.5.2.2.1. Georges Bank mortality indicators categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

	1. Exploitation Rate		2. Median Length		3. Proportion of the Exploitable Stock Comprised of Recruits (surveys)	
Description	Landings numbers by area/ Number > 77 mm from survey (sexes combined)		Median length Greater Than 77 mm (sexes combined)		Recruit and fully recruited abundance below (see 5 & 6) (sexes combined)	
Survey	NEFSC		NEFSC		NEFSC	
Season	Fall	Spring	Fall	Spring	Fall	Spring
1981						
1982	0.63	0.18	93	85	0.13	0.28
1983	0.69	0.34	87	88	0.13	0.38
1984	0.70	0.49	85	83	0.20	0.35
1985	1.00	0.39	90	87	0.22	0.33
1986	0.66	0.16	79	87	0.18	0.32
1987	0.90	0.38	77	97	0.29	0.21
1988	0.58	0.10	91	75	0.10	0.50
1989	0.58	0.20	94	83	0.10	0.32
1990	0.84	0.31	89	74	0.19	0.47
1991	0.75	0.29	97	86	0.09	0.24
1992	1.00	0.24	86	93	0.30	0.15
1993	0.99	0.18	94	81	0.21	0.49
1994	0.83	0.69	97	81	0.16	0.36
1995	0.85	0.48	96	97	0.18	0.00
1996	0.80	0.13	103	108	0.19	0.06
1997	0.66	1.00	87	90	0.14	0.20
1998	0.65	0.52	93	87	0.11	0.16
1999	0.54	0.10	101	91	0.12	0.18
2000	0.62	0.22	89	79	0.16	0.43
2001	0.54	0.13	104	82	0.16	0.39
2002	0.35	0.14	105	109	0.16	0.09
2003	0.70	0.10	90	104	0.22	0.12
2004	0.55	0.16	114	103	0.13	0.28
2005	0.69	0.19	112	105	0.16	0.09
2006	0.58	0.15	121	96	0.04	0.21
2007	0.57	0.12	113	116	0.04	0.04
2005-07 Avg.	0.62	0.16	115	106	0.08	0.11
25th	0.58	0.14	89.0	83.0	0.12	0.15
Median	0.67	0.20	93.5	87.5	0.16	0.26
75th	0.82	0.37	102.5	97.0	0.19	0.36

Table 7.5.2.2.2. Georges Bank abundance indicators categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

	4. Spawning Stock Abundance Index		5. Full Recruit Abundance (survey)		6.Recruit Abundance (survey)		7. Sex ratio (Full recruits)		8. Sex ratio (recruits)	
Description	Mean weight per tow of mature females		Abundance adjusted for Minimun Legal Size (sexes Combined)		Recruits 10mm below Minimum Legal Size		Proportion Females from Survey Full Recruits Adjusted for Minimum Legal Size		Proportion Females from Survey Recruits 10 mm Below Minimum Legal Size	
Survey	NEFSC		NEFSC		NEFSC		NEFSC		NEFSC	
Season	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
1981										
1982	618	78	0.90	0.36	0.21	0.14	0.60	0.41	0.55	0.29
1983	561	95	0.82	0.17	0.19	0.11	0.56	0.70	0.37	0.06
1984	282	27	0.74	0.08	0.25	0.04	0.53	0.64	0.55	0.00
1985	423	24	0.62	0.16	0.12	0.08	0.56	0.24	0.68	0.67
1986	342	245	0.82	0.36	0.31	0.17	0.63	0.46	0.39	0.45
1987	442	89	0.58	0.16	0.36	0.04	0.55	0.54	0.29	0.22
1988	520	224	1.10	0.55	0.17	0.55	0.50	0.56	0.58	0.48
1989	619	90	1.00	0.24	0.17	0.11	0.50	0.57	0.32	0.29
1990	524	73	0.70	0.16	0.23	0.15	0.57	0.64	0.50	0.57
1991	740	139	0.95	0.23	0.15	0.07	0.71	0.67	0.46	0.64
1992	619	122	0.73	0.33	0.32	0.06	0.68	0.69	0.57	0.57
1993	551	72	0.69	0.32	0.14	0.31	0.74	0.41	0.43	0.43
1994	617	21	0.76	0.07	0.13	0.04	0.66	0.61	0.11	0.25
1995	740	39	0.64	0.13	0.12	0.00	0.79	0.70	1.00	1.00
1996	795	394	0.66	0.44	0.08	0.03	0.66	0.72	0.45	0.25
1997	499	38	0.88	0.07	0.25	0.02	0.59	0.91	0.49	1.00
1998	838	42	0.87	0.11	0.14	0.02	0.65	0.60	0.43	1.00
1999	1142	312	1.10	0.57	0.09	0.12	0.61	0.78	0.46	0.43
2000	689	79	0.80	0.22	0.27	0.16	0.64	0.55	0.36	0.27
2001	1332	199	1.20	0.43	0.24	0.27	0.78	0.71	0.41	0.39
2002	1821	400	1.85	0.50	0.34	0.05	0.69	0.65	0.38	0.70
2003	845	618	0.83	0.71	0.28	0.09	0.77	0.75	0.43	0.39
2004	1108	304	1.00	0.29	0.11	0.11	0.83	0.66	0.28	0.49
2005	1119	362	0.94	0.35	0.11	0.03	0.83	0.82	0.65	0.38
2006	1791	339	1.15	0.40	0.03	0.10	0.85	0.81	0.23	0.64
2007	1490	596	1.09	0.55	0.09	0.02	0.90	0.80	0.54	0.25
2005-07 Avg.	1467	432	1.06	0.44	0.08	0.05	0.86	0.81	0.47	0.42
25th	531	72	0.7	0.2	0.1	0.0	0.6	0.6	0.4	0.3
Median	654	108	0.8	0.3	0.2	0.1	0.7	0.7	0.4	0.4
75th	1043	310	1.0	0.4	0.3	0.1	0.8	0.7	0.5	0.6

Table 7.5.2.2.3. Georges Bank fishery performance indicators categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

	10. Effort	11. Landings	12. Median Length (mm)	13. Gross CPUE	14. Set Over Days	15. Price per Pound		16. Revenue		17. Revenue per Trap	
Description	Traps	Pounds	Commercial Catch	Pounds per trap	Average Soak Time of Traps	Un-adjusted	Adjusted to Unprocessed Fish CPI	Un-adjusted	Adjusted to Unprocessed Fish CPI	Un-adjusted	Adjusted to Unprocessed Fish CPI
Survey	MA				MA						
1981	25,856		93	99.3		$ 2.19	$ 5.95	$ 5,625,974	$ 15,279,491	$ 218	$ 591
1982	27,560	2,869,179	94	104.1		$ 2.31	$ 5.60	$ 6,622,516	$ 16,079,469	$ 240	$ 583
1983	28,922	3,190,519	96	110.3		$ 2.42	$ 5.58	$ 7,722,257	$ 17,789,031	$ 267	$ 615
1984	30,651	3,297,873	99	107.6		$ 2.69	$ 5.80	$ 8,872,508	$ 19,114,863	$ 289	$ 624
1985	34,950	3,281,639	93	93.9		$ 2.49	$ 5.27	$ 8,170,025	$ 17,309,618	$ 234	$ 495
1986	36,950	2,739,754	92	74.1		$ 2.62	$ 5.09	$ 7,174,416	$ 13,946,744	$ 194	$ 377
1987	39,674	2,901,630	93	73.1		$ 3.09	$ 5.37	$ 8,979,928	$ 15,573,761	$ 226	$ 393
1988	39,732	3,123,164	92	78.6		$ 2.99	$ 4.87	$ 9,324,047	$ 15,224,470	$ 235	$ 383
1989	39,163	2,923,852	93	74.7		$ 2.80	$ 4.76	$ 8,188,455	$ 13,912,924	$ 209	$ 355
1990	35,891	3,153,726	93	87.9		$ 2.48	$ 4.09	$ 7,823,615	$ 12,904,713	$ 218	$ 360
1991	36,784	3,483,213	93	94.7		$ 2.59	$ 4.21	$ 9,022,113	$ 14,652,636	$ 245	$ 398
1992	38,745	3,754,377	92	96.9		$ 2.90	$ 4.52	$ 10,906,428	$ 16,964,002	$ 281	$ 438
1993	43,041	3,405,884	91	79.1		$ 2.77	$ 4.29	$ 9,417,511	$ 14,610,681	$ 219	$ 339
1994	47,894	2,967,382	92	62.0	6.9	$ 2.96	$ 4.46	$ 8,790,503	$ 13,223,879	$ 184	$ 276
1995	44,480	2,676,978	92	60.2	7.0	$ 3.06	$ 4.36	$ 8,203,504	$ 11,661,656	$ 184	$ 262
1996	42,008	2,516,081	92	59.9	6.8	$ 3.39	$ 4.96	$ 8,518,952	$ 12,467,760	$ 203	$ 297
1997	40,974	2,677,613	92	65.3	8.3	$ 3.29	$ 4.48	$ 8,806,136	$ 12,005,221	$ 215	$ 293
1998	45,327	2,635,930	92	58.2	6.8	$ 3.19	$ 4.22	$ 8,395,591	$ 11,126,907	$ 185	$ 245
1999	47,941	3,176,962	96	66.3	7.1	$ 3.70	$ 4.70	$ 11,741,014	$ 14,933,045	$ 245	$ 311
2000	41,464	2,610,913	93	63.0	7.1	$ 3.61	$ 4.43	$ 9,437,540	$ 11,567,061	$ 228	$ 279
2001	40,899	3,101,798	93	75.8	7.1	$ 3.50	$ 4.46	$ 10,870,877	$ 13,833,590	$ 266	$ 338
2002	47,387	3,444,830	94	72.7	6.7	$ 3.54	$ 4.49	$ 12,184,961	$ 15,473,371	$ 257	$ 327
2003	42,834	3,938,924	95	92.0	7.1	$ 3.96	$ 4.92	$ 15,578,976	$ 19,368,026	$ 364	$ 452
2004	43,922	4,362,874	105	99.3	7.6	$ 4.16	$ 4.89	$ 18,130,107	$ 21,337,809	$ 413	$ 486
2005	40,694	5,276,968	108	129.7	7.9	$ 4.73	$ 5.16	$ 24,964,995	$ 27,230,462	$ 613	$ 669
2006	40,175	4,939,026	108	122.9	7.7	$ 4.27	$ 4.36	$ 21,074,205	$ 21,553,568	$ 525	$ 536
2007	42,307	4,550,686	104	107.6	7.3	$ 4.76	$ 4.76	$ 21,649,327	$ 21,649,327	$ 512	$ 512
2005-07 Avg.	41,059	4,922,227	107	120.1	7.6	$ 4.59	$ 4.76	$ 22,568,716	$ 23,432,350	$ 550	$ 572
25th	36,867	2,804,466	92	69.5	6.9	$ 2.65	$ 4.44	$ 8,195,980	$ 13,528,734	$ 216	$ 319
Median	40,694	3,153,726	93	79.1	7.1	$ 3.06	$ 4.76	$ 8,979,928	$ 15,078,758	$ 237	$ 380
75th	42,937	3,464,021	96	99.3	7.5	$ 3.58	$ 5.13	$ 11,323,721	$ 17,789,031	$ 281	$ 486

Table 7.5.2.3.1. Mortality indicators for Southern New England categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

Description	1. Exploitation Rate								2. Median Length						3. Percent of the Exploitable Stock Comprised of Recruits (surveys)					
	Landings numbers by area/ Number > 77 mm from survey (sexes combined)								Median length Greater Than 77 mm (sexes combined)						Recruit and fully recruited abundance below (see 6 & 7) (sexes combined)					
Survey	NMFS		RI		CT		NJ		NMFS		RI		CT		NMFS		RI		CT	
Season	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
1979											84.0	85.0					0.70	0.59		
1980											82.0	82.0					0.77	0.70		
1981			6815	10506							79.0	78.0					0.86	0.89		
1982	3342929	3973896	1412914	2511848					86.5	87.0	81.0	80.0			0.42	0.37	0.83	0.82		
1983	5670186	11571026	1892101	1188063					83.0	84.0	82.5	80.0			0.54	0.52	0.62	0.75		
1984	4117653	15370895	1126961	983530	332861				92.5	88.5	79.5	81.0	82.0		0.43	0.33	0.79	0.70	0.66	
1985	6531352	3902191	1863747	4157589	637918	703268			86,5	80.5	80.0	84.0	80.5	82.0	0.54	0.77	0.82	0.64	0.76	0.75
1986	11931624	10840655	2258843	2651686	303193	906839			86.0	91.5	81.0	79.5	83.0	81.0	0.61	0.39	0.83	0.79	0.63	0.74
1987	7246224	14829143	1108014	3149093	348514	664260			87.0	81.0	80.0	79.5	80.0	82.0	0.22	0.70	0.82	0.87	0.76	0.66
1988	8992880	19887643	473937	4411261	763841	1428534			85.5	88.0	80.0	81.0	82.0	83.0	0.51	0.45	0.73	0.70	0.70	0.63
1989	4766593	12900550	1276412	3701593	833412	676400	3593802	2547590	82.5	88.0	80.0	80.5	80.5	80.5	0.66	0.16	0.87	0.89	0.76	0.71
1990	4687041	9084134	2013996	2427124	516981	518791	5566917	8069224	86.5	81.5	80.0	79.5	82.0	80.5	0.44	0.71	0.71	0.91	0.72	0.78
1991	8754062	20920909	1356682	809030	445562	319945	3494890	6682791	91.0	82.5	81.0	80.0	80.5	81.0	0.37	0.57	0.81	0.84	0.79	0.73
1992	6167042	18037815	1543049	4089080	403069	364696	8031103	3019276	89.0	89.5	80.0	80.0	81.5	80.5	0.45	0.34	0.78	0.84	0.71	0.82
1993	8418563	9200327	418959	488357	322775	553603	1716548	2346403	88.0	82.0	80.0	81.0	80.0	79.5	0.45	0.65	0.85	0.74	0.85	0.87
1994	30263227	16766745	1305610	6988855	411430	1396702	2741003	1937877	100.0	85.5	82.0	81.5	81.5	80.0	0.33	0.41	0.74	0.85	0.74	0.84
1995	4863836	112482120	1298644	4035073	717920	728338	1264999	790948	90.0	90.5	79.5	80.0	81.0	80.5	0.47	0.35	0.87	0.91	0.76	0.81
1996	2276342	18718515	909577	2034145	1129047	957274	1143259	1243979	86.5	84.0	80.0	81.0	80.5	80.5	0.59	0.65	0.86	0.84	0.78	0.80
1997	3174698	3219682	781345	2105658	453442	502891	717967	2381177	82.0	84.0	80.5	79.5	80.0	81.0	0.65	0.60	0.81	0.90	0.83	0.74
1998	4429238	12096290	1798094	2677163	965948	368515	1443518	1488367	84.0	81.0	79.5	80.0	80.0	80.0	0.55	0.87	0.90	0.81	0.85	0.83
1999	8446671	4703517	3955780	2966835	683935	308062	883598	1366415	84.5	80.5	81.5	80.5	80.0	80.0	0.56	0.86	0.75	0.85	0.84	0.84
2000	6167399	7065812	3135333	2633680	471515	257201	8011021	1495627	83.0	82.0	81.0	81.0	80.0	80.5	0.65	0.59	0.80	0.78	0.83	0.79
2001	5075424	10036131	1739137	1670935	437960	209423	2608545	1834080	88.0	85.0	80.0	80.0	79.5	80.5	0.42	0.43	0.91	0.84	0.89	0.78
2002	9102281	2759195	4464838	1050550	1198857	260804	3367475	1558476	85.0	82.0	79.0	80.0	79.5	80.5	0.49	0.71	0.97	0.85	0.92	0.78
2003	7244702	5768180	417014	1475587	349135	560686	3685560	1902486	88.0	84.0	82.0	80.5	80.0	80.0	0.46	0.58	0.78	0.84	0.81	0.85
2004	7332437	13132624	359891	290061	672501	738497	782381	1855358	95.5	88.5	81.5	82.0	80.0	81.0	0.34	0.57	0.85	0.82	0.86	0.77
2005	5495848	10815023	391836	467189	960980	1109924	1636255	6269680	91.0	88.5	81.0	81.5	81.0	81.0	0.37	0.37	0.83	0.77	0.82	0.81
2006	5645107	5033481	405481	279407	2569197	1036086	3686955	3345050	89.5	88.5	81.0	81.0	79.5	80.0	0.37	0.45	0.90	0.80	0.97	0.81
2007	4363467	9075956	311228	782786	1352533	578728	1498285	1872805	90.5	83.0	81.5	81.0	80.0	80.5	0.40	0.71	0.88	0.83	0.91	0.83
2005-07 Avg.	5168141	8308153	369515	509794	1627570	908246	2273832	3829178	90.3	86.7	81.2	81.2	80.2	80.5	0.38	0.51	0.87	0.80	0.90	0.82
25th	4706929	6092588	446448	896280	409340	366606	1354258	1527052	85.0	82.0	80.0	80.0	80.0	80.3	0.40	0.40	0.79	0.78	0.75	0.75
Median	5918614	10827839	1298644	2105658	577450	578728	2608545	1902486	87.0	84.0	80.0	80.5	80.3	80.5	0.45	0.57	0.83	0.84	0.80	0.79
75th	8147032	15235457	1830921	3057964	865304	822668	3639681	2783433	90.0	88.4	81.0	81.0	81.1	81.0	0.55	0.69	0.87	0.85	0.85	0.82

Table 7.5.2.3.2. Abundance indicators for Southern New England categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

Description	4. Spawning Stock Abundance Index: Number of recruit & fully recruited females * maturity curve						5. Full Recruit Abundance (survey): Abundance adjusted for Minimun Legal Size (sexes Combined)						6.Recruit Abundance (survey): Recruits 10mm below Minimum Legal Size					
Survey	NMFS		RI		CT		NMFS		RI		CT		NMFS		RI		CT	
Season	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
1979									0.24	0.23					0.55	0.38		
1980									0.21	0.26					0.71	0.71		
1981			232	144					0.21	0.31					1.29	0.89		
1982	206	139	51	51			0.41	0.34	0.13	0.11			0.30	0.20	0.63	0.26		
1983	123	52	139	165			0.23	0.12	0.27	0.06			0.27	0.13	0.43	0.94		
1984	273	66	226	238	2477		0.45	0.11	0.33	0.31	4.35		0.33	0.06	1.25	1.03	8.62	
1985	193	269	155	61	1103	1226	0.32	0.35	0.21	0.44	1.60	1.57	0.38	1.19	0.97	0.25	5.03	4.73
1986	124	91	132	148	1640	797	0.17	0.20	0.25	0.14	4.82	1.23	0.27	0.13	1.25	0.75	8.22	3.45
1987	181	80	480	92	1981	988	0.38	0.13	0.57	0.20	3.03	2.05	0.11	0.32	2.53	0.79	9.46	3.90
1988	159	216	675	187	1149	681	0.24	0.11	1.45	0.12	2.07	1.29	0.25	0.09	3.95	0.36	4.82	2.16
1989	204	63	572	223	901	1267	0.31	0.19	0.38	0.16	1.80	2.20	0.59	0.04	2.62	0.95	5.68	5.50
1990	319	119	233	276	1925	2511	0.48	0.17	0.54	0.12	3.52	2.52	0.37	0.41	1.34	1.60	8.89	8.92
1991	243	75	355	891	2307	2848	0.42	0.13	0.64	0.17	2.94	5.22	0.24	0.18	2.72	4.05	11.10	13.99
1992	277	94	533	169	2014	3803	0.52	0.18	0.54	0.79	4.30	3.37	0.42	0.09	1.94	0.74	10.51	15.41
1993	176	106	610	1001	3518	2451	0.29	0.19	1.56	0.14	3.16	1.36	0.23	0.35	9.09	7.46	18.16	9.33
1994	88	63	464	169	3597	1238	0.11	0.14	1.10	2.62	5.55	0.92	0.06	0.10	3.07	0.83	16.03	5.00
1995	251	14	511	141	2376	3491	0.38	0.02	0.52	0.15	4.31	3.49	0.33	0.01	3.57	1.26	13.43	14.63
1996	474	53	852	489	3192	4110	0.76	0.09	1.00	0.12	3.34	3.62	1.09	0.16	6.18	1.88	11.94	14.09
1997	328	227	888	679	7569	6340	0.44	0.51	1.31	0.36	6.94	8.26	0.80	0.77	5.52	2.35	34.30	23.46
1998	232	82	254	344	2716	8175	0.44	0.07	0.31	0.28	2.82	7.43	0.53	0.45	2.86	1.44	15.79	35.47
1999	115	218	190	411	2685	8720	0.24	0.19	0.46	0.34	3.20	6.96	0.30	1.17	1.37	1.88	17.44	36.43
2000	230	102	230	369	1841	4677	0.28	0.23	0.40	0.33	2.23	4.85	0.51	0.34	1.65	1.54	10.97	18.36
2001	257	57	362	642	1598	3555	0.33	0.18	0.21	0.44	1.18	4.75	0.24	0.14	2.07	2.27	10.03	16.96
2002	130	253	29	765	385	2159	0.14	0.33	0.03	0.43	0.28	2.80	0.13	0.83	0.83	2.52	3.08	9.93
2003	100	50	233	132	1255	736	0.17	0.17	0.29	0.43	1.13	0.71	0.14	0.24	1.00	0.39	4.79	4.00
2004	181	81	269	503	661	553	0.23	0.09	0.26	0.07	0.60	0.74	0.12	0.12	1.43	1.84	3.79	2.48
2005	176	59	414	186	501	507	0.21	0.10	0.30	0.41	0.45	0.51	0.12	0.06	1.48	1.12	2.02	2.17
2006	97	146	639	620	232	492	0.18	0.18	0.24	0.33	0.03	0.43	0.10	0.15	2.19	2.74	1.09	1.79
2007	174	54	413	189	200	629	0.24	0.06	0.32	0.67	0.10	0.43	0.16	0.13	2.24	0.71	1.11	2.11
2005-07 Avg.	149	87	488	332	311	542	0.21	0.11	0.29	0.47	0.19	0.46	0.13	0.12	1.97	1.52	1.40	2.02
25th	137	60	228	156	1053	767	0.23	0.11	0.24	0.14	1.17	1.07	0.14	0.11	1.25	0.74	4.81	3.68
Median	187	81	355	223	1883	2159	0.30	0.17	0.32	0.28	2.88	2.20	0.27	0.15	1.65	1.03	9.18	8.92
75th	249	134	522	496	2529	3679	0.41	0.19	0.54	0.41	3.71	4.18	0.38	0.34	2.72	1.88	12.31	15.02

Table 7.5.2.3.2. Continued Abundance indicators for Southern New England categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.

Description	7. Sex ratio (Full recruits) Percent Females from Survey Full Recruits Adjusted for Minimum Legal Size						8. Sex ratio (recruits) Percent Females from Survey Recruits 10 mm Below Minimum Legal Size						9. Recruitment Indices Index of Young of Year or Larvae		
Survey	NMFS		RI		CT		NMFS		RI		CT		611 ELIS (larvae)	611 WLIS (larvae)	539 RI (YoY)
Season	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	annual	summer	Fall
1979			0.00	0.14					0.44	0.50					
1980			0.30	0.25					0.56	0.41					
1981			0.33	0.29					0.39	0.43					
1982	0.53	0.57	0.11	0.75			0.60	0.49	0.33	0.44					
1983	0.59	0.56	0.28	0.41			0.43	0.43	0.59	0.46				14.48	
1984	0.67	0.86	0.55	0.65	0.52		0.47	0.37	0.29	0.39	0.58		0.43	6.89	
1985	0.48	0.56	0.08	0.44	0.51	0.71	0.60	0.60	0.45	0.56	0.56	0.52	0.53	66.75	
1986	0.50	0.46	0.21	0.36	0.31	0.55	0.57	0.31	0.42	0.54	0.47	0.55	0.90	4.58	
1987	0.56	0.53	0.59	0.17	0.54	0.46	0.44	0.36	0.60	0.41	0.52	0.51	0.78	18.98	
1988	0.61	0.57	0.16	0.71	0.45	0.62	0.65	0.88	0.44	0.56	0.51	0.48	0.74	49.27	
1989	0.43	0.43	0.25	0.40	0.26	0.43	0.62	0.63	0.32	0.48	0.36	0.51	0.74	5.88	
1990	0.66	0.40	0.23	0.29	0.37	0.66	0.62	0.58	0.42	0.40	0.46	0.60	0.81	19.66	1.26
1991	0.48	0.46	0.40	0.56	0.45	0.28	0.45	0.74	0.26	0.38	0.42	0.48	0.55	9.97	1.50
1992	0.53	0.65	0.32	0.50	0.26	0.51	0.55	0.66	0.43	0.45	0.38	0.62	1.44	14.12	0.63
1993	0.62	0.43	0.36	0.21	0.44	0.71	0.45	0.46	0.41	0.63	0.46	0.61	1.19	26.23	0.51
1994	0.62	0.39	0.26	0.50	0.41	0.67	0.25	0.49	0.23	0.58	0.45	0.56	0.98	96.52	1.23
1995	0.67	0.89	0.18	0.00	0.22	0.45	0.63	0.50	0.32	0.42	0.42	0.58	1.46	18.20	0.33
1996	0.49	0.66	0.24	0.47	0.61	0.67	0.59	0.34	0.40	0.51	0.53	0.61	0.31	12.07	0.15
1997	0.49	0.32	0.20	0.27	0.42	0.39	0.57	0.53	0.28	0.54	0.52	0.62	0.21	13.69	0.99
1998	0.52	0.43	0.23	0.21	0.36	0.42	0.46	0.47	0.23	0.56	0.44	0.60	0.55	4.85	0.57
1999	0.50	0.60	0.16	0.57	0.26	0.39	0.37	0.39	0.29	0.43	0.41	0.66	2.83	39.70	0.93
2000	0.62	0.29	0.25	0.44	0.38	0.37	0.56	0.57	0.48	0.49	0.41	0.67	0.78	14.28	0.34
2001	0.72	0.33	0.44	0.56	0.51	0.37	0.55	0.20	0.34	0.60	0.42	0.48	0.32	9.46	0.75
2002	0.63	0.53	1.00	0.33	0.41	0.35	0.57	0.59	0.09	0.67	0.35	0.54	0.64	1.99	0.26
2003	0.58	0.25	0.33	0.33	0.54	0.35	0.54	0.22	0.38	0.81	0.60	0.50	0.25	2.60	0.79
2004	0.60	0.72	0.64	0.47	0.30	0.36	0.62	0.60	0.35	0.72	0.50	0.50	0.45	6.10	0.42
2005	0.61	0.67	0.58	0.21	0.68	0.53	0.48	0.00	0.36	0.45	0.48	0.53	0.49	6.90	0.53
2006	0.46	0.84	0.50	0.39	1.00	0.30	0.52	0.62	0.41	0.50	0.58	0.72	0.71	1.70	0.46
2007	0.53	0.26	0.15	0.67	0.14	0.42	0.54	0.58	0.34	0.53	0.46	0.56	0.37	18.10	0.36
2005-07 Avg.	0.53	0.59	0.41	0.42	0.61	0.41	0.51	0.40	0.37	0.49	0.51	0.61	0.52	8.90	0.45
25th	0.50	0.41	0.20	0.27	0.31	0.37	0.46	0.37	0.32	0.43	0.42	0.51	0.45	6.10	0.38
Median	0.57	0.53	0.26	0.40	0.42	0.43	0.55	0.50	0.38	0.50	0.46	0.56	0.67	13.69	0.55
75th	0.62	0.63	0.40	0.50	0.51	0.59	0.59	0.60	0.43	0.56	0.52	0.61	0.83	18.98	0.90

Table 7.5.2.3.3. Fishery performance indicators for Southern New England categorized as positive (white), neutral (grey), or negative (black) based on quartile rankings.
Note: RI traps are omitted due to incomplete data

	10. Effort	11. Landings	12. Median Length (mm)	13. Gross CPUE	14. Set Over Days		15. Price per Pound		16. Revenue		17. Revenue per Trap	
Description	Traps	Pounds	Commercial Catch	Pounds per trap	Average Soak Time of Traps		Un-adjusted	Adjusted to Unprocessed Fish CPI	Un-adjusted	Adjusted to Unprocessed Fish CPI	Un-adjusted	Adjusted to Unprocessed Fish CPI
Survey	NY, CT, MA, NMFS				MA	CT						
1981	105505	4056478	88	38.4		3.4	$ 2.19	$ 5.95	$ 8,887,410	$ 24,137,170	$ 84	$ 229
1982	102931	5906144	87	57.4		3.3	$ 2.31	$ 5.60	$ 13,632,308	$ 33,099,244	$ 132	$ 322
1983	126109	8348849	87	66.2		3.1	$ 2.42	$ 5.58	$ 20,207,355	$ 46,549,769	$ 160	$ 369
1984	193380	9380605	87	48.5		4.0	$ 2.69	$ 5.80	$ 25,237,324	$ 54,371,093	$ 131	$ 281
1985	209548	8725837	85	41.6		4.2	$ 2.49	$ 5.27	$ 21,723,993	$ 46,026,052	$ 104	$ 220
1986	202411	9665000	85	47.7		4.3	$ 2.62	$ 5.09	$ 25,309,112	$ 49,199,780	$ 125	$ 243
1987	210893	9828141	85	46.6		4.5	$ 3.09	$ 5.37	$ 30,416,003	$ 52,750,039	$ 144	$ 250
1988	244554	10471886	86	42.8		4.6	$ 2.99	$ 4.87	$ 31,263,288	$ 51,047,251	$ 128	$ 209
1989	289935	13095369	87	45.2		4.7	$ 2.80	$ 4.76	$ 36,674,517	$ 62,313,315	$ 126	$ 215
1990	291632	16801315	87	57.6		4.9	$ 2.48	$ 4.09	$ 41,679,908	$ 68,749,197	$ 143	$ 236
1991	316488	15624054	88	49.4		5.1	$ 2.59	$ 4.21	$ 40,468,955	$ 65,724,832	$ 128	$ 208
1992	353735	13741319	88	38.8		5.4	$ 2.90	$ 4.52	$ 39,918,397	$ 62,089,601	$ 113	$ 176
1993	414956	13249692	88	31.9		5.5	$ 2.77	$ 4.29	$ 36,636,336	$ 56,838,992	$ 88	$ 137
1994	451696	14934012	87	33.1	3.8	5.5	$ 2.96	$ 4.46	$ 44,240,168	$ 66,552,123	$ 98	$ 147
1995	443833	17643475	87	39.8	5.2	5.9	$ 3.06	$ 4.36	$ 54,067,805	$ 76,859,854	$ 122	$ 173
1996	516487	20699061	87	40.1	4.8	6.3	$ 3.39	$ 4.96	$ 70,082,910	$ 102,568,599	$ 136	$ 199
1997	546347	21900572	87	40.1	5.1	6.2	$ 3.29	$ 4.48	$ 72,026,624	$ 98,192,388	$ 132	$ 180
1998	588422	20668196	87	35.1	5.2	6.2	$ 3.19	$ 4.22	$ 65,829,397	$ 87,245,510	$ 112	$ 148
1999	577865	19865719	87	34.4	5.2	6.7	$ 3.70	$ 4.70	$ 73,417,209	$ 93,377,153	$ 127	$ 162
2000	403314	13390787	87	33.2	5.6	7.1	$ 3.61	$ 4.43	$ 48,403,021	$ 59,324,854	$ 120	$ 147
2001	378579	9841368	87	26.0	6.1	7.0	$ 3.50	$ 4.46	$ 34,491,057	$ 43,891,135	$ 91	$ 116
2002	354443	8049022	87	22.7	5.8	7.3	$ 3.54	$ 4.49	$ 28,470,789	$ 36,154,328	$ 80	$ 102
2003	249699	5632772	89	22.6	6.4	7.7	$ 3.96	$ 4.92	$ 22,278,377	$ 27,696,825	$ 89	$ 111
2004	241613	5478450	90	22.7	6.4	7.6	$ 4.16	$ 4.89	$ 22,765,931	$ 26,793,835	$ 94	$ 111
2005	217542	5727571	90	26.3	6.9	7.4	$ 4.73	$ 5.16	$ 27,096,764	$ 29,555,680	$ 125	$ 136
2006	232712	6589572	90	28.3	7.1	7.5	$ 4.27	$ 4.36	$ 28,116,877	$ 28,756,436	$ 121	$ 124
2007	213615	5366015	90	25.1	6.9	8.7	$ 4.76	$ 4.76	$ 25,528,152	$ 25,528,152	$ 120	$ 120
2005-07 Avg.	221290	5894386	90	26.6	7.0	7.9	$ 4.59	$ 4.76	$ 27,026,124	$ 28,060,330	$ 121.63	$ 126
25th	212254	7319297	87	30.1	5.2	4.6	$ 2.65	$ 4.44	$ 25,273,218	$ 34,626,786	$ 100.81	$ 136
Median	289935	9841368	87	38.8	5.7	5.5	$ 3.06	$ 4.76	$ 31,263,288	$ 53,560,566	$ 123.19	$ 174
75th	409135	15279033	88	45.9	6.4	7.1	$ 3.58	$ 5.13	$ 42,960,038	$ 66,552,123	$ 127.87	$ 215

Table 8.1.1. CSM-based turn of the crank reference points from ASMFC 2006 (abundance in millions).

Variable	GOM	GBK	SNE
Fishing mortality			
Fishing mortality threshold	0.68	0.26	1.06
Fishing mortality target	0.56	0.22	0.94
Recent fishing mortality 2004-2006	1.01	0.27	1.15
Fishing mortality below threshold?	No	No	No
Fishing mortality near or below target?	No	No	No
Abundance			
Abundance threshold	71.86	8.48	15.83
Abundance target	80.30	9.47	16.94
Recent abundance 2004-2006	104.09	8.59	6.22
Abundance above threshold?	Yes	Yes	No
Abundance near or above target?	Yes	No	No

12.0 Figures

Figure 1.1. Lobster conservation management areas and biological stock assessment areas.

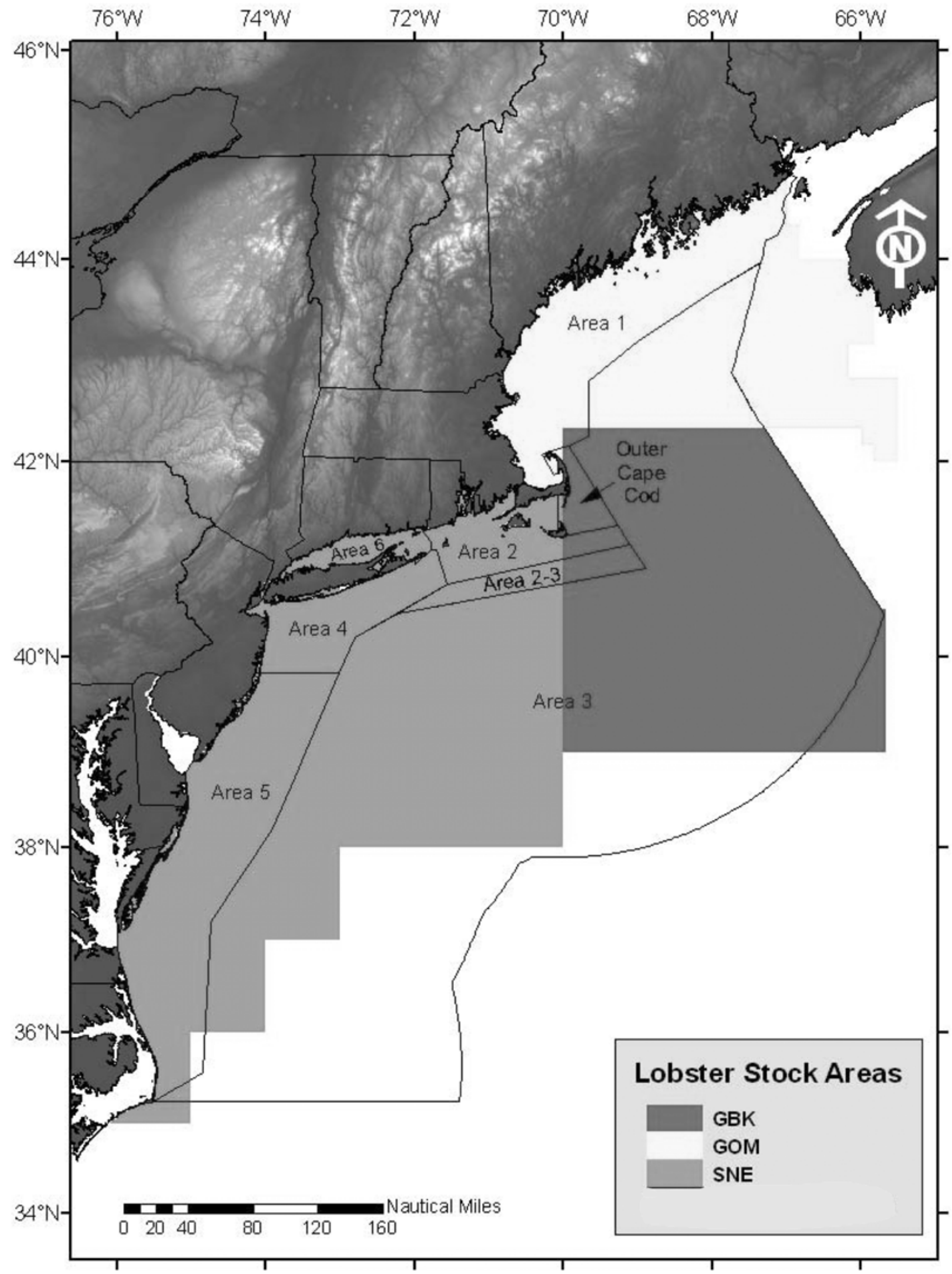


Figure 2.1.1. Mean lipofuscin concentration (%) ±STDEV) at predicted age for Long Island Sound lobster.

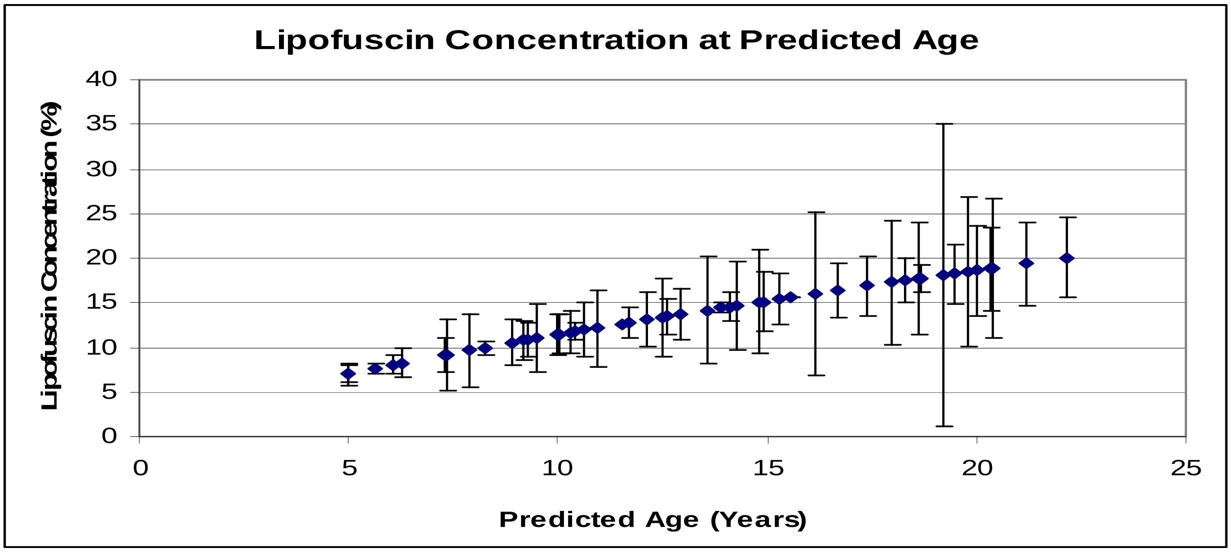


Figure 2.1.2. Mean predicted age (years) at length (mm) for lobster from Long Island Sound.

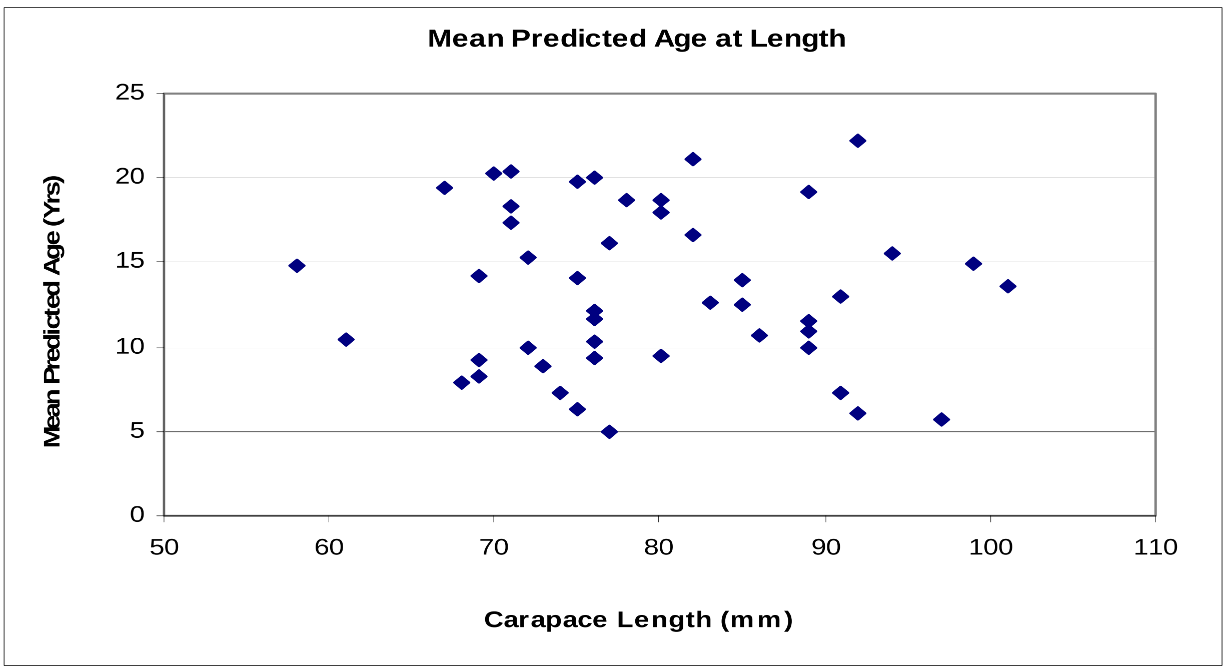


Figure 2.4.1 Biological stock assessment areas

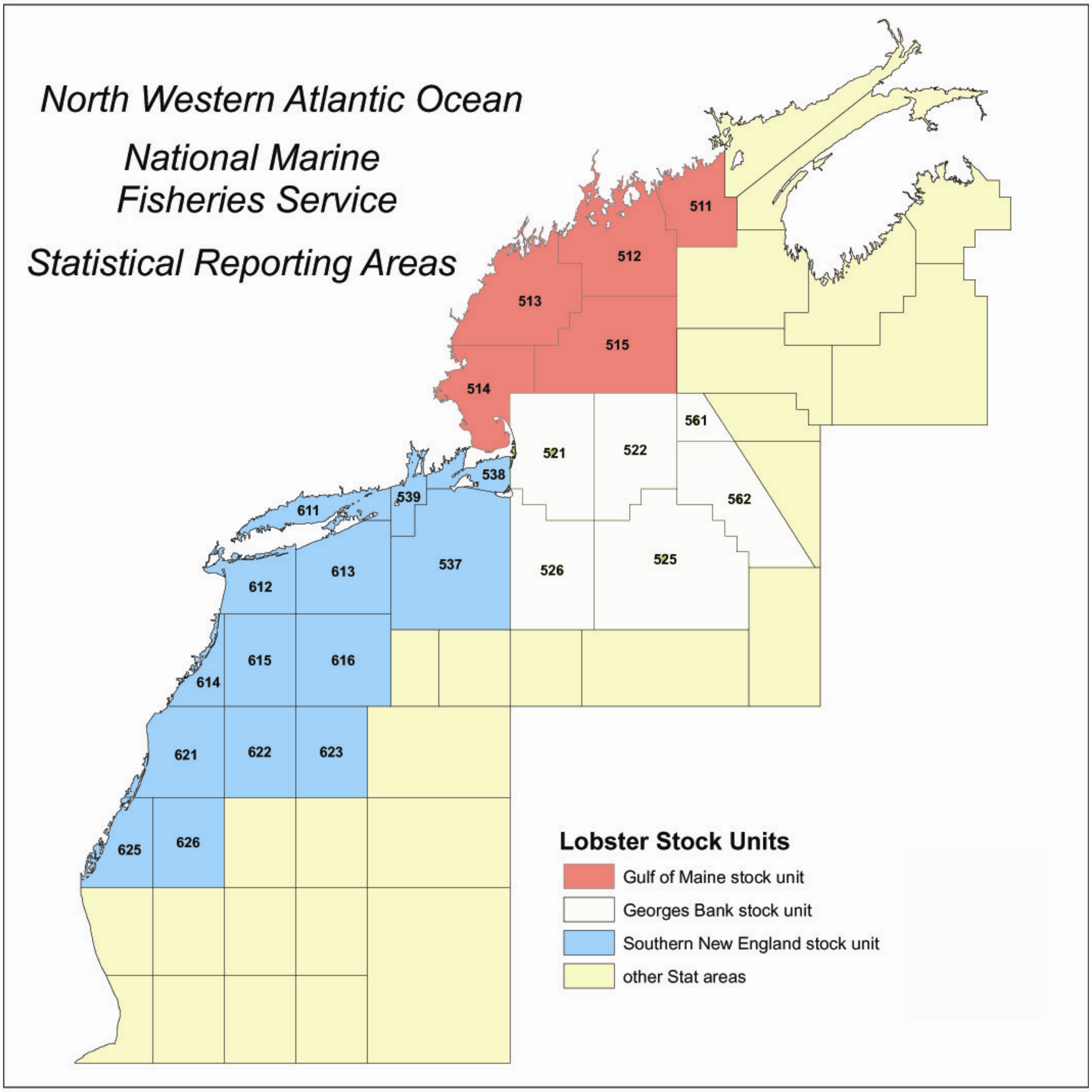


Figure 2.5.1. Long Island Sound 'Stress-Area' index. Bars show annual cumulative area with bottom water temperature.

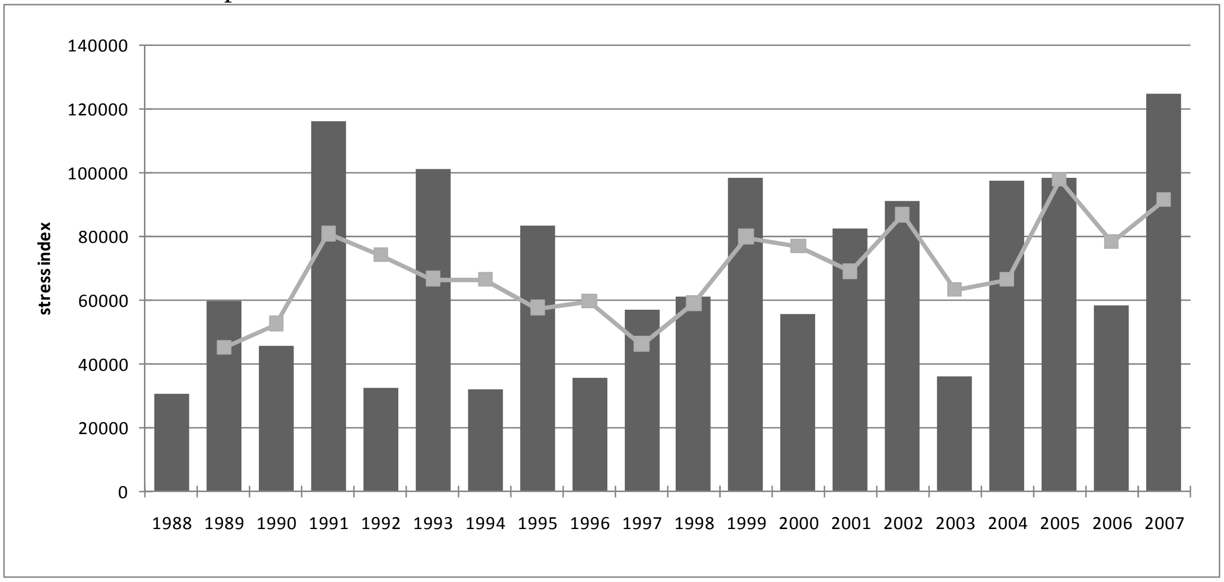


Figure 2.5.2. Lobster abundance versus 'stress area' index.
Spring-fall average geometric mean catch per tow from the CTDEP Trawl Survey shows a negative relationship with the 2-year stress-area index for 1997-2007 (correlation df=10, r=0.603, p=0. 048).

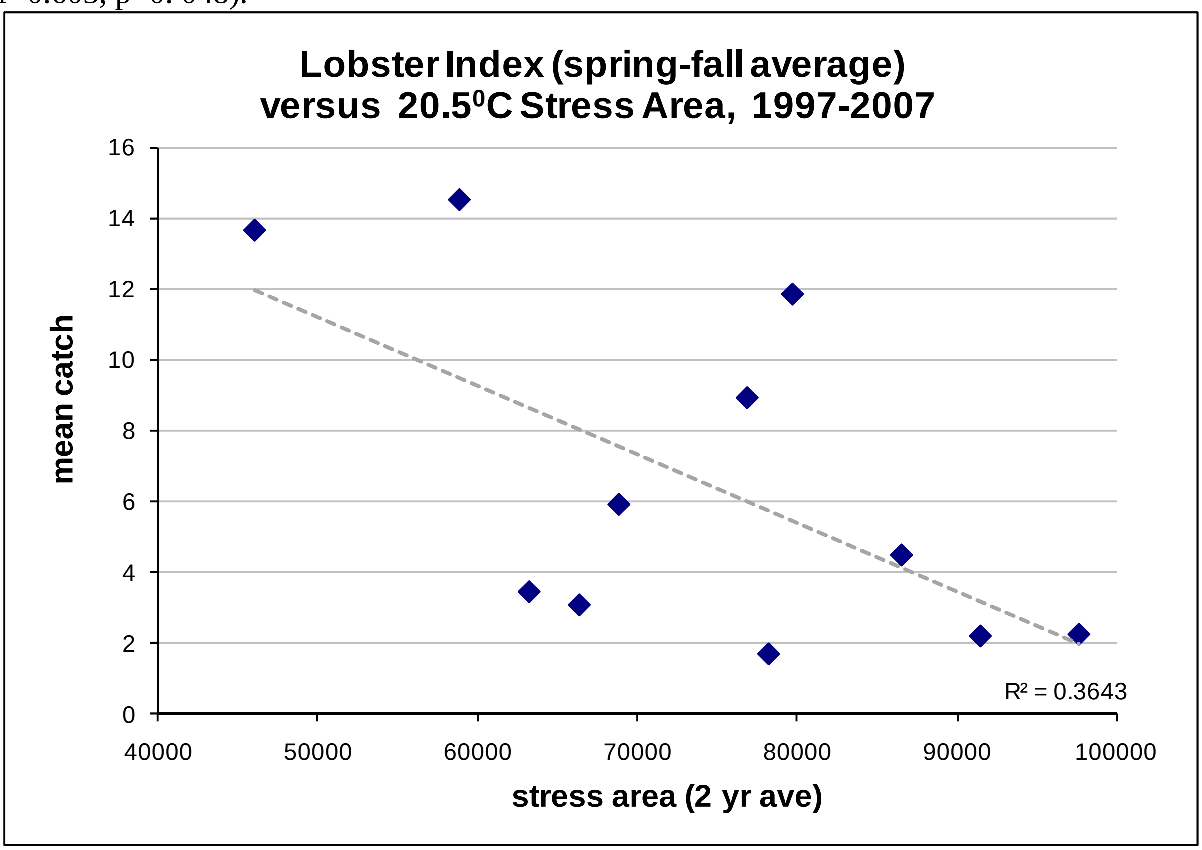
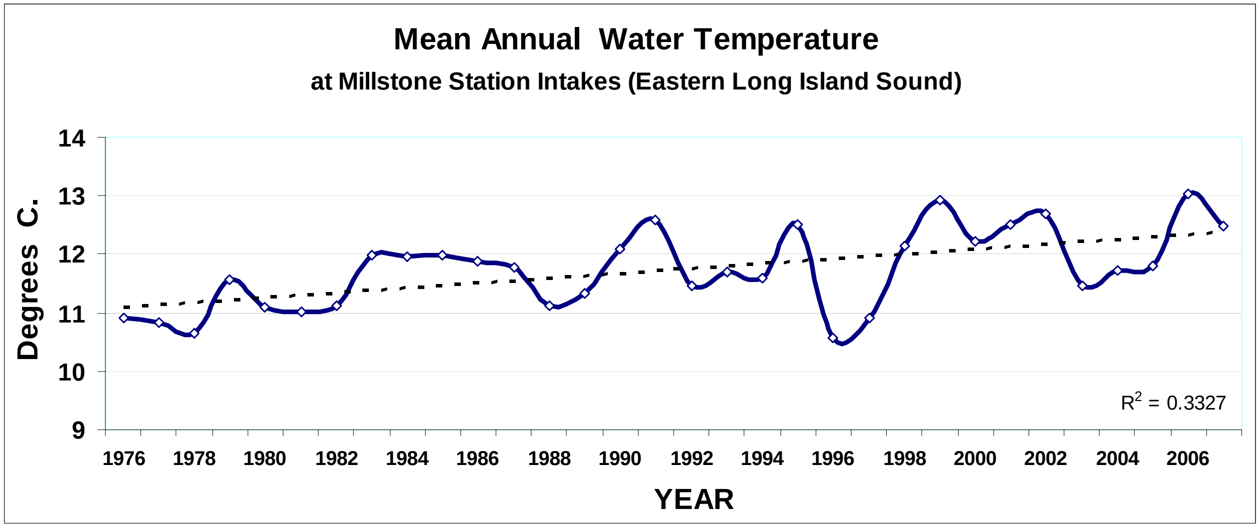


Figure 2.5.3. Long term increasing temperature trends in Southern New England waters.
The 31-year time series for inshore (20 depth) eastern Long Island Sound shows a significant positive slope of 0.04 degrees/yr (df=30, p=0.001); data provided by Dominion Nuclear Connecticut. The 49-year time series for surface waters of Narragansett Bay and Rhode Island Sound has slightly larger positive slope of 0.5 degrees/year (df=48, p<0.0001); data provided by RI DEM.



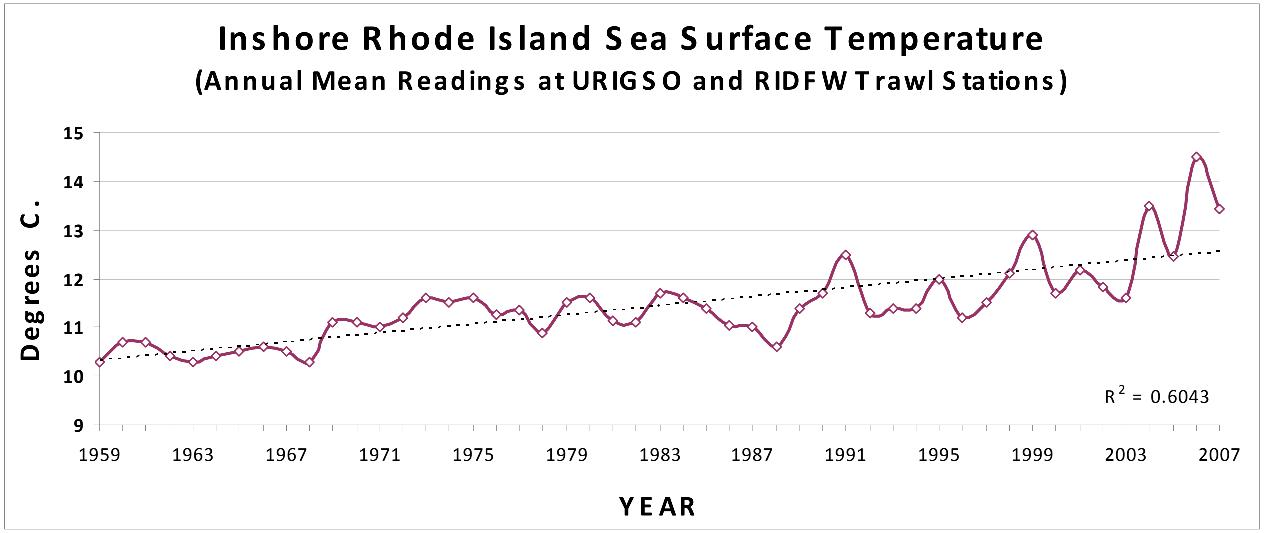
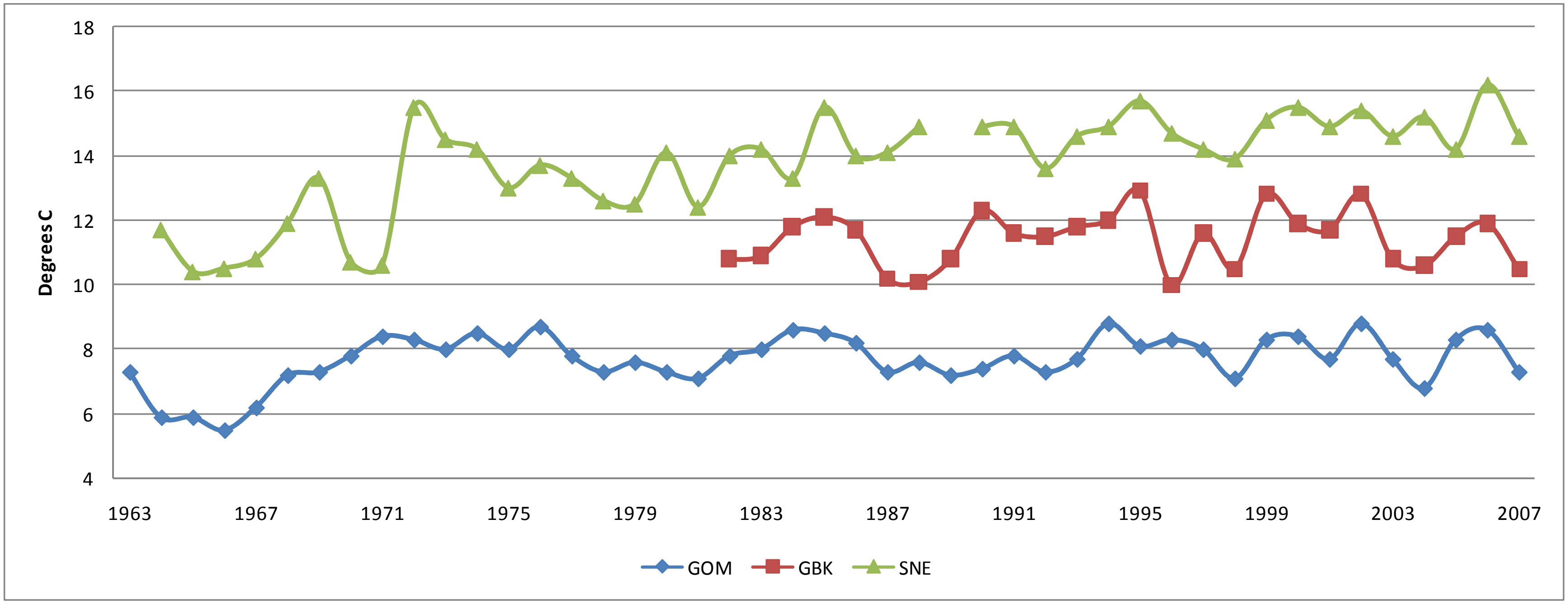


Figure 2.5.4. Fall bottom water temperature readings at NEFSC trawl stations in three lobster stock areas.
Although all areas show an increasing trend, only Southern New England (SNE) has a statistically significant slope = 0.09 degrees/yr (df=43, $p<0.0001$). Median values are shown for 1979-1994 (or 1982-1994) and 1995-2007 for fall and spring cruises, and 1963(4)-1978 for the fall offshore stations. Strata used for each stock area are listed below:
Gulf of Maine: Offshore – 1260, 1270, 1280, 1290, 1300, 1360, 1370, 1380, 1390, 1400; Inshore – 3590, 3600, 3610, 660
Georges Bank: Offshore - 1090,1100,1120,1130,1140,1150,1160,1170,1180 1190, 1200,1210,1220,1230,1240,1250
Southern New England: Offshore – 1050 (northern stratum only); Inshore – 3450,3460,3520,3550



GULF of MAINE

	Median Years	Inshore Mean	Offshore Mean	Mean All Stations
FALL	1963-1978		7.6	
	1979-1994	9.5	7.7	7.8
	1995-2007	10.0	8.1	8.3
SPRING	1979-1994	4.3	5.7	5.6
	1995-2007	4.2	6.3	6.1

GEORGES BANK

	Median Years	Mean All Stations
FALL		
	1982-1994	11.6
	1995-2007	11.6
SPRING	1979-1994	6.5
	1995-2007	6.1

SOUTHERN NEW ENGLAND

	Median Years	Inshore Mean	Offshore Mean	Mean All Stations
FALL	1964-1978		12.6	
	1979-1994	12.6	14.1	13.9
	1995-2007	13.9	14.9	14.6
SPRING	1979-1994	4.6	4.3	4.4
	1995-2007	4.9	4.5	4.8

Figure 2.6.1. Relationship between the prevalence of shell disease and average bottom water temperature. Disease prevalence and bottom water temperature were recorded in research (ventless) lobster traps set in the vicinity of Millstone Power Station, Waterford CT, on 2-3 day sets May-November. Data provided by Donald Landers, Dominion Nuclear Connecticut.

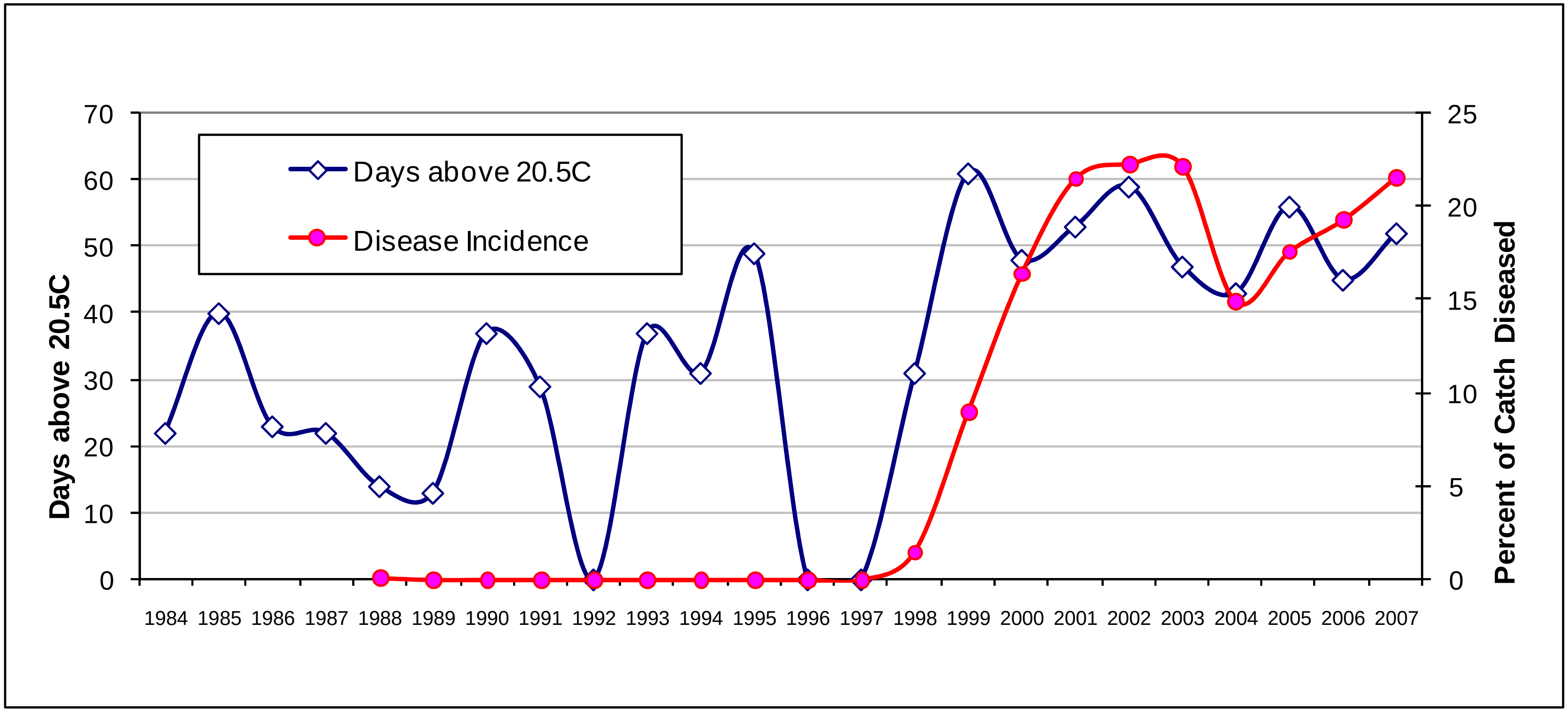


Figure 3.1.1. Comparison of percent cumulative length frequency of eggers from Vineyard Sound/ Coxes Ledge 1894

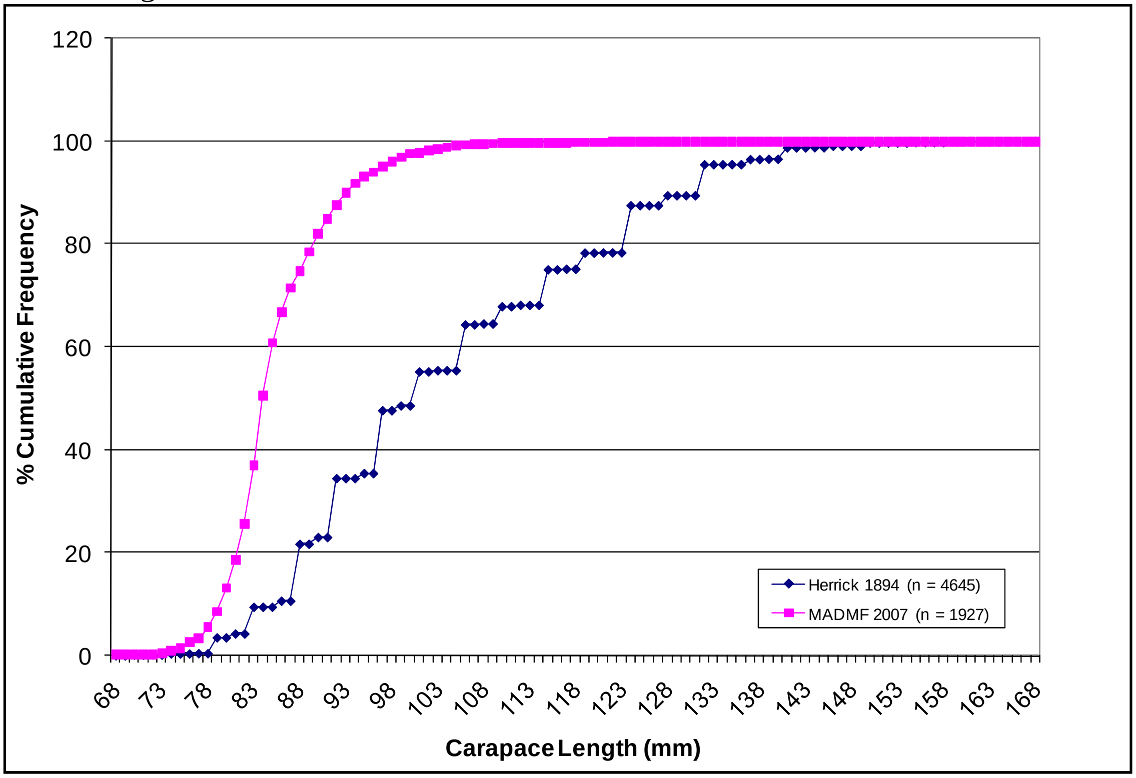


Figure 3.2.2.1. Gulf of Maine landings (mt) by state 1981 to 2007.
2007 landings are preliminary estimates.

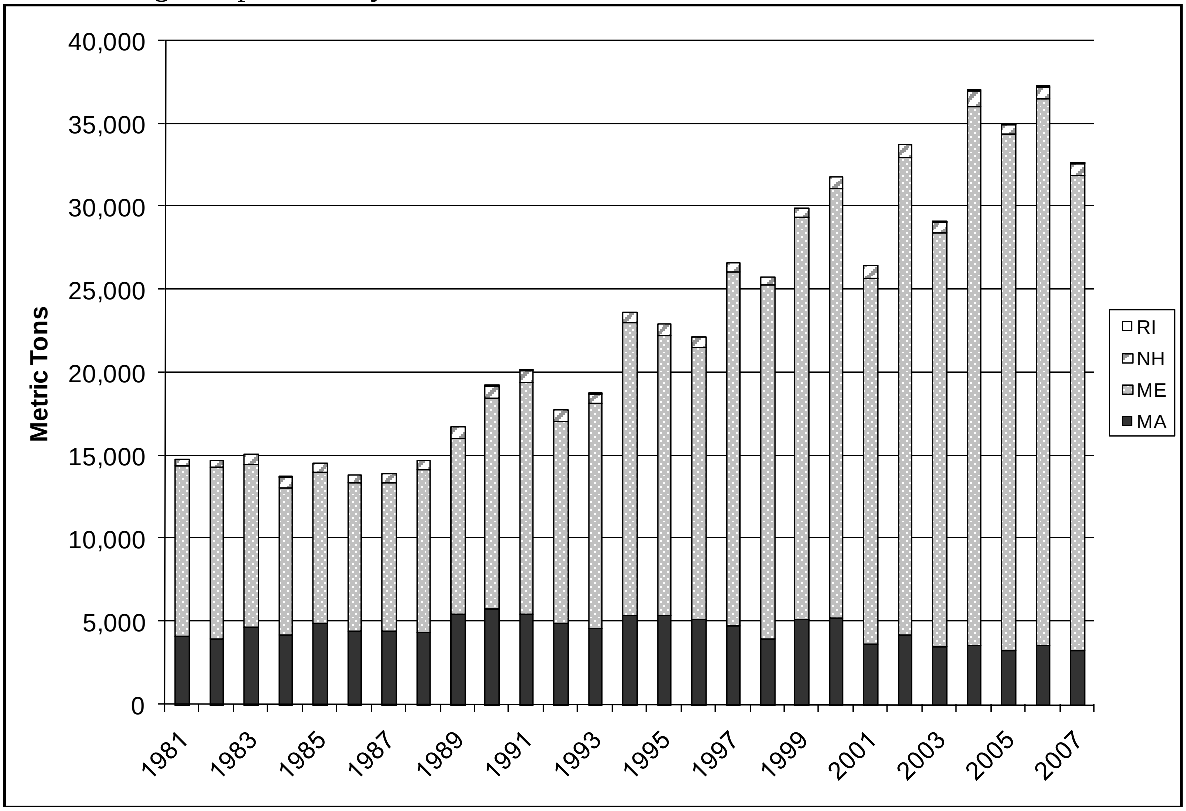


Table 3.2.2.2. Number of traps reported fished by state in the Gulf of Maine stock unit.

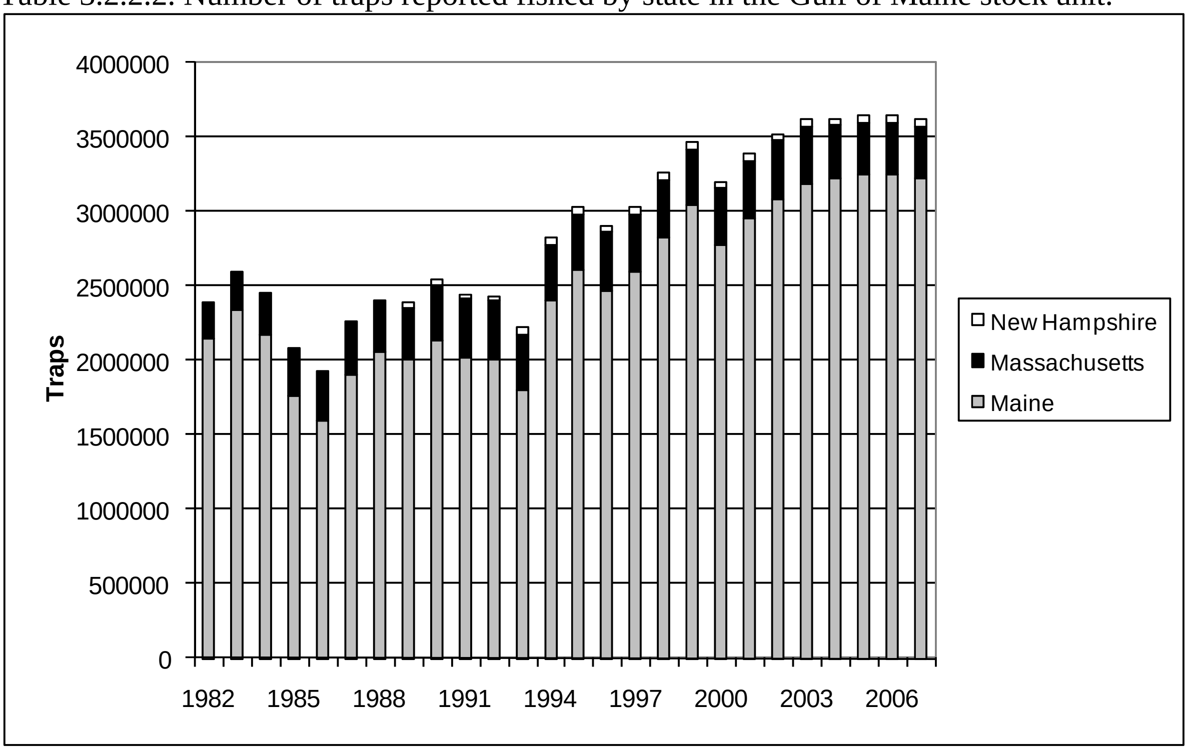


Figure 3.2.3.1. Georges Bank landings (mt) by state from 1981 to 2007. 2007 landings are preliminary estimates.

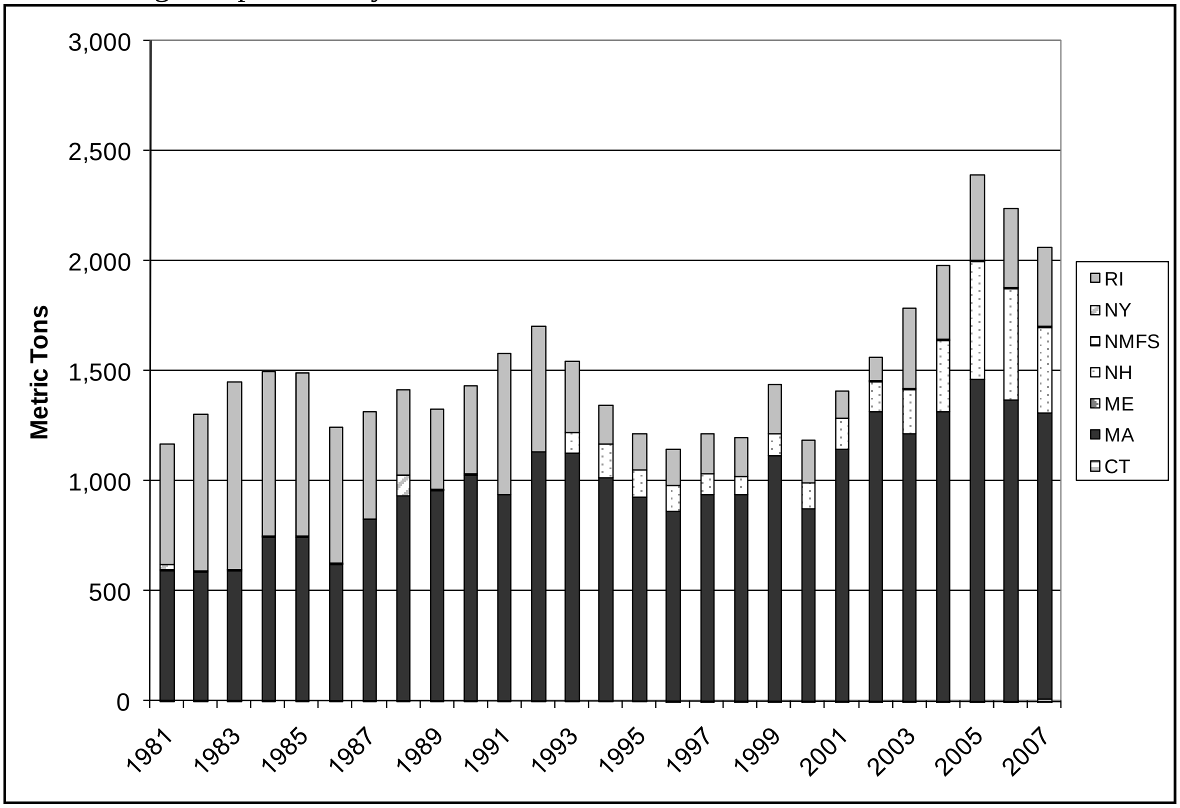


Figure 3.2.3.2. Number of traps reported fished on Georges Bank by Massachusetts as an index of effort.

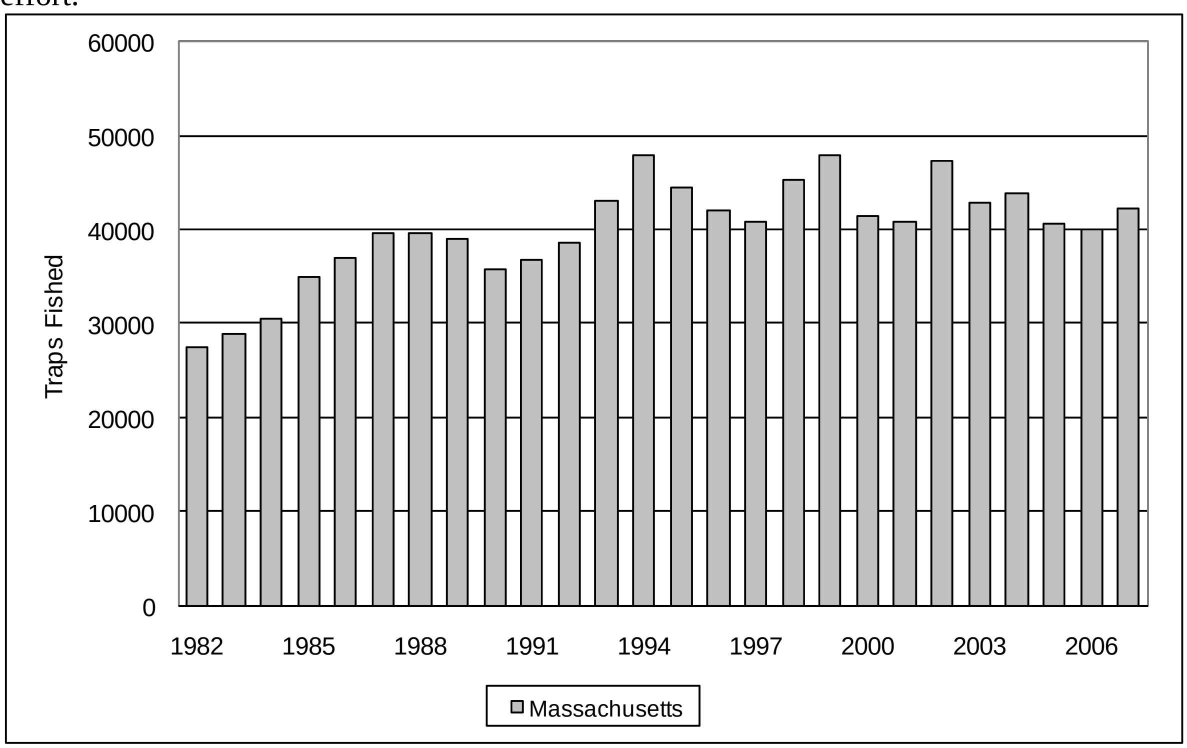


Figure 3.2.4.1. Southern New England landings (mt) by state from 1981 to 2007. 2007 landings are preliminary estimates.

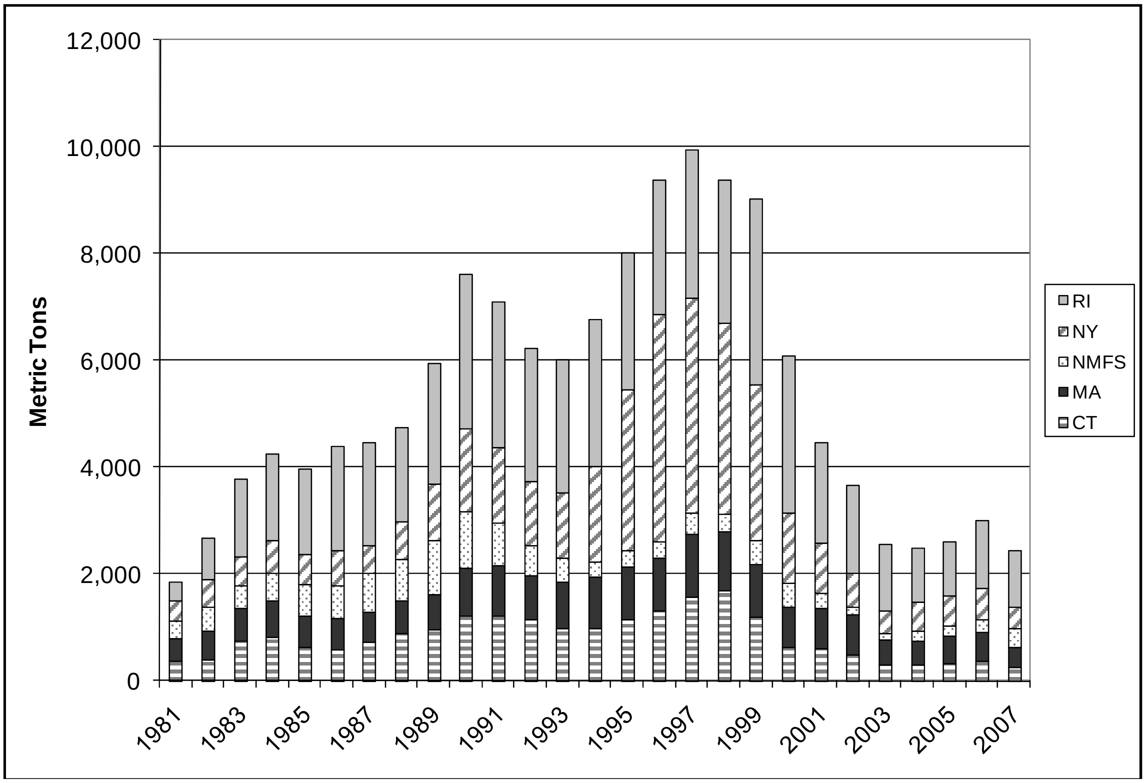


Figure 3.2.4.2. Number of traps reported fished in Southern New England stock unit. Note: RI traps not included due to incomplete data

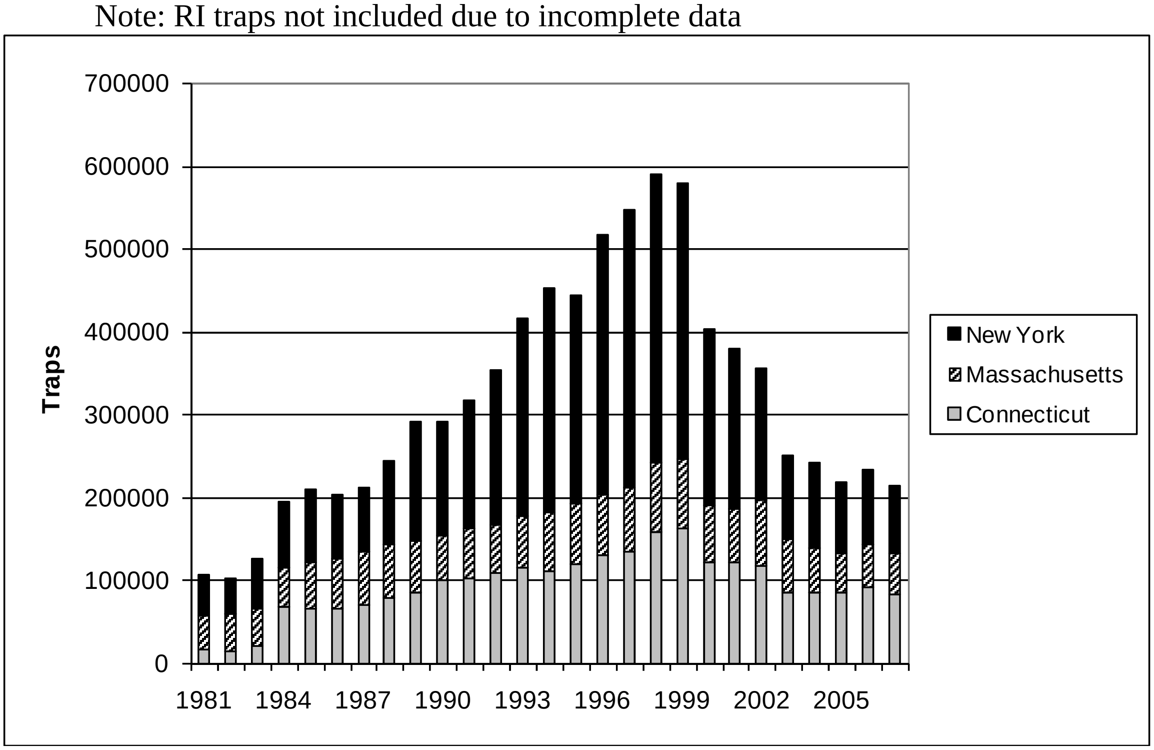


Figure 5.1.1.4.1. Gulf of Maine commercial catch female size structure.
Median length (dark midline) bounded by minimum, 25, 75, and 99 percentiles.

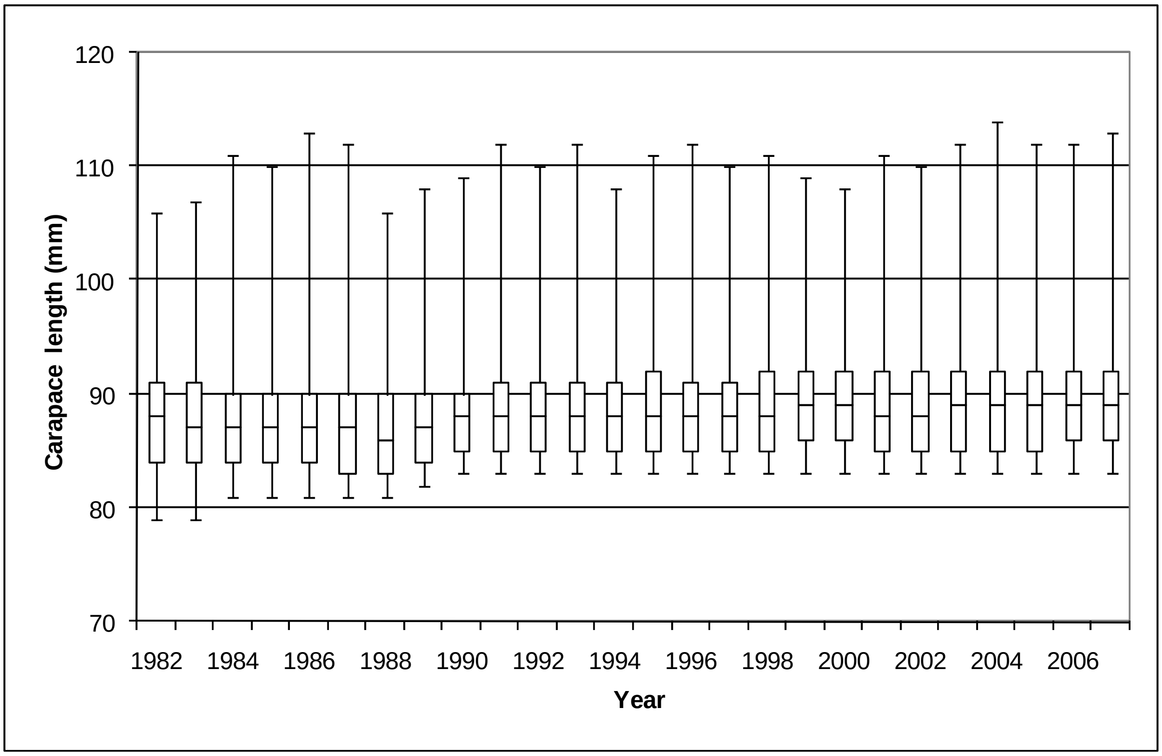


Figure 5.1.1.4.2. Gulf of Maine commercial catch male size structure.
Median length (dark midline) bounded by minimum, 25, 75, and 99 percentiles.

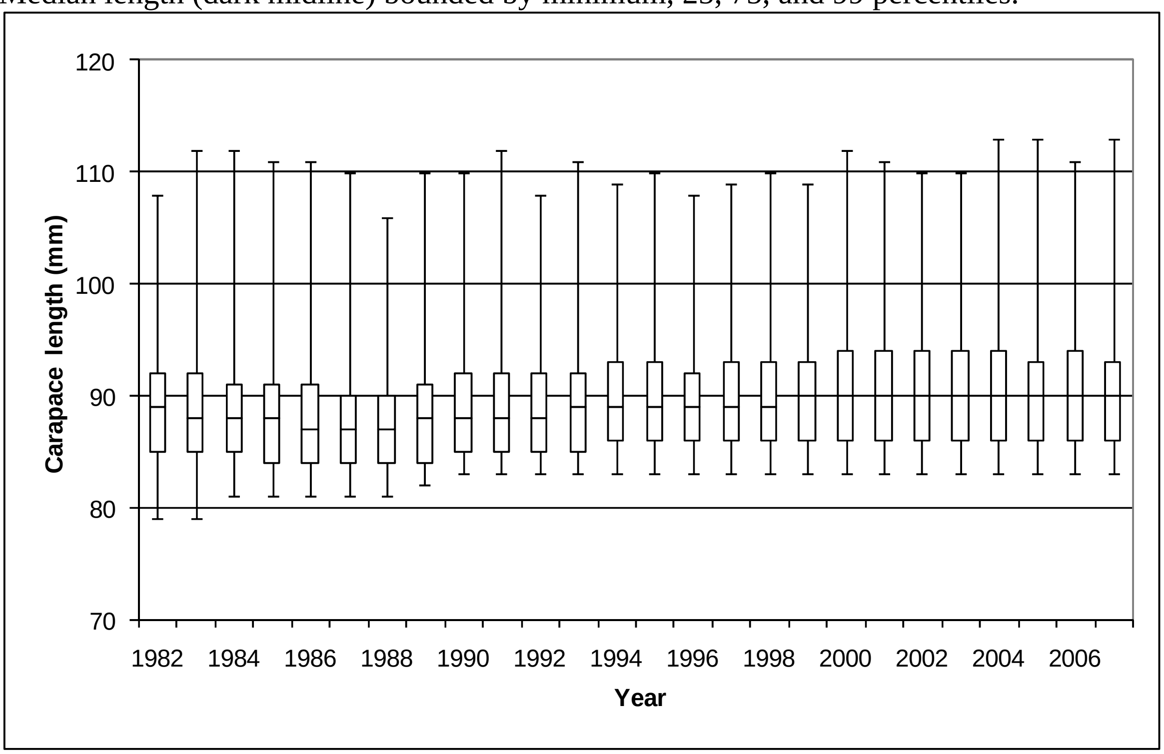


Figure 5.1.1.4.3. Georges Bank commercial catch female size structure.
Median length (dark midline) bounded by minimum, 25, 75, and 99 percentiles.

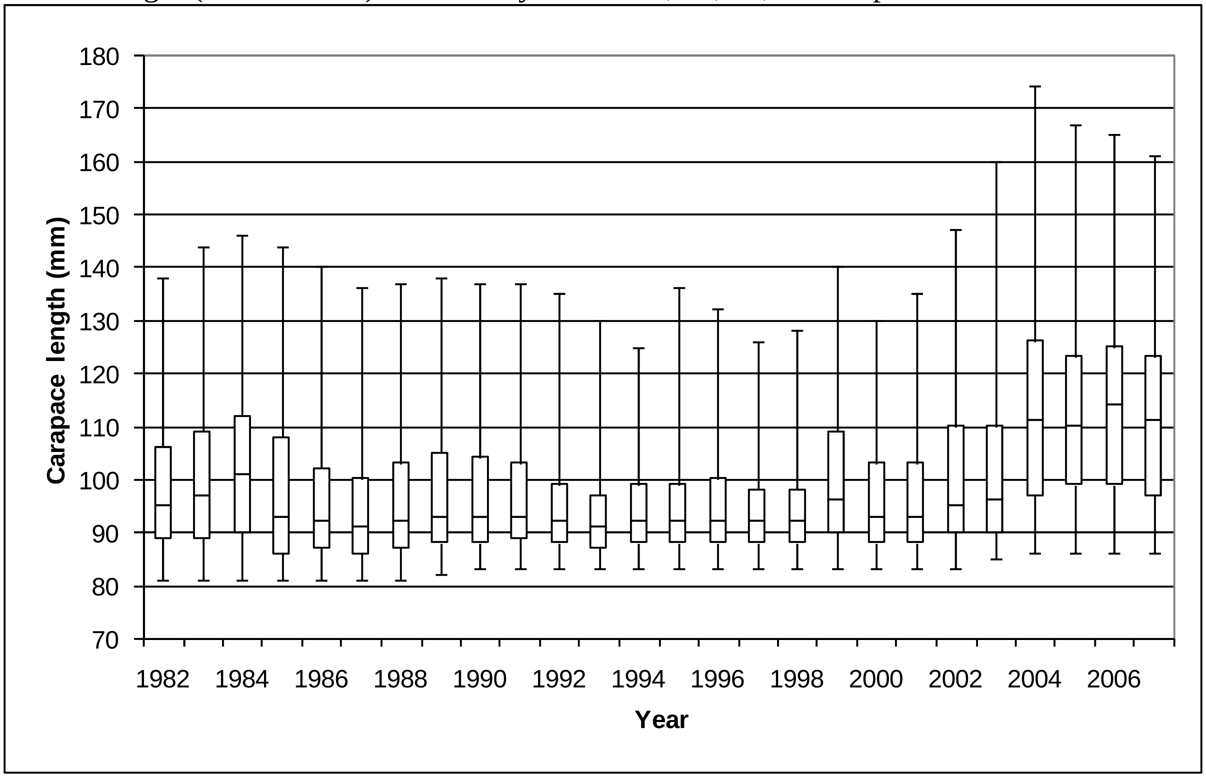


Figure 5.1.1.4.4. Georges Bank commercial catch male size structure.
Median length (dark midline) bounded by minimum, 25, 75, and 99 percentiles.

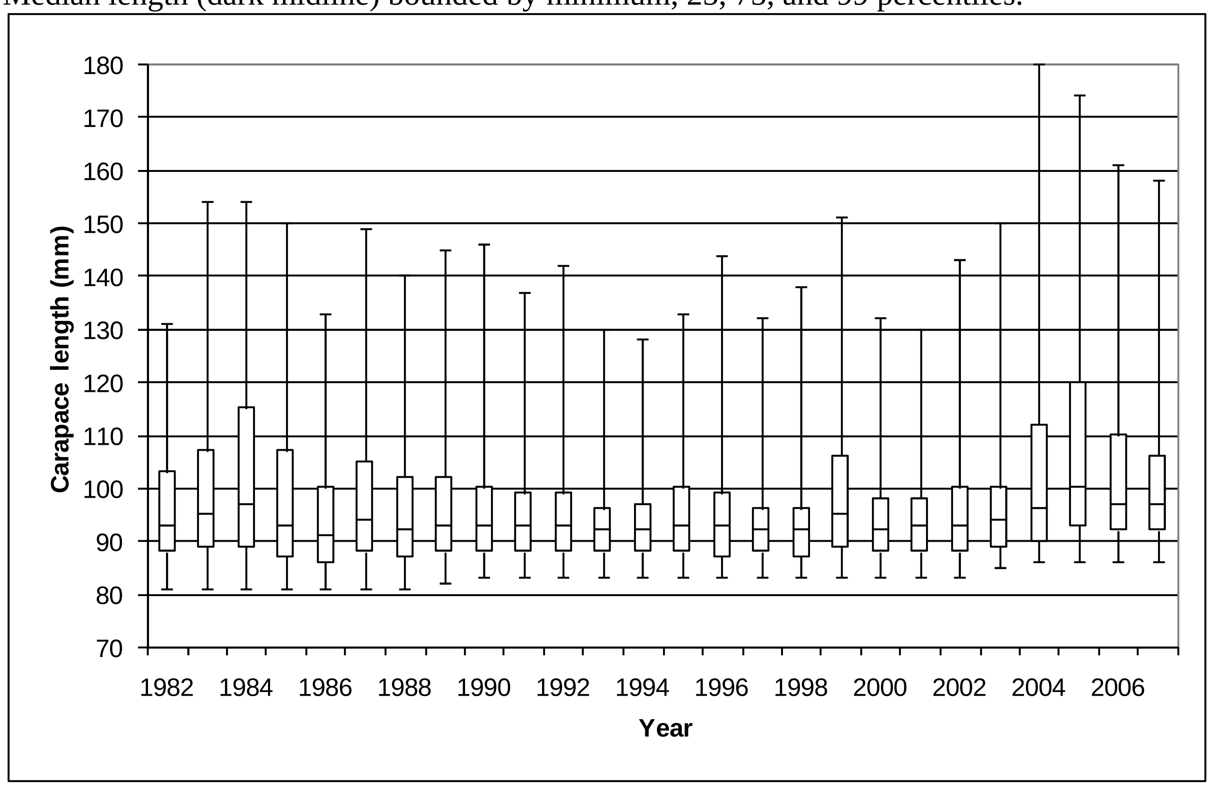


Figure 5.1.1.4.5. Southern New England commercial catch female size structure. Median length (dark midline) bounded by minimum, 25, 75, and 99 percentiles.

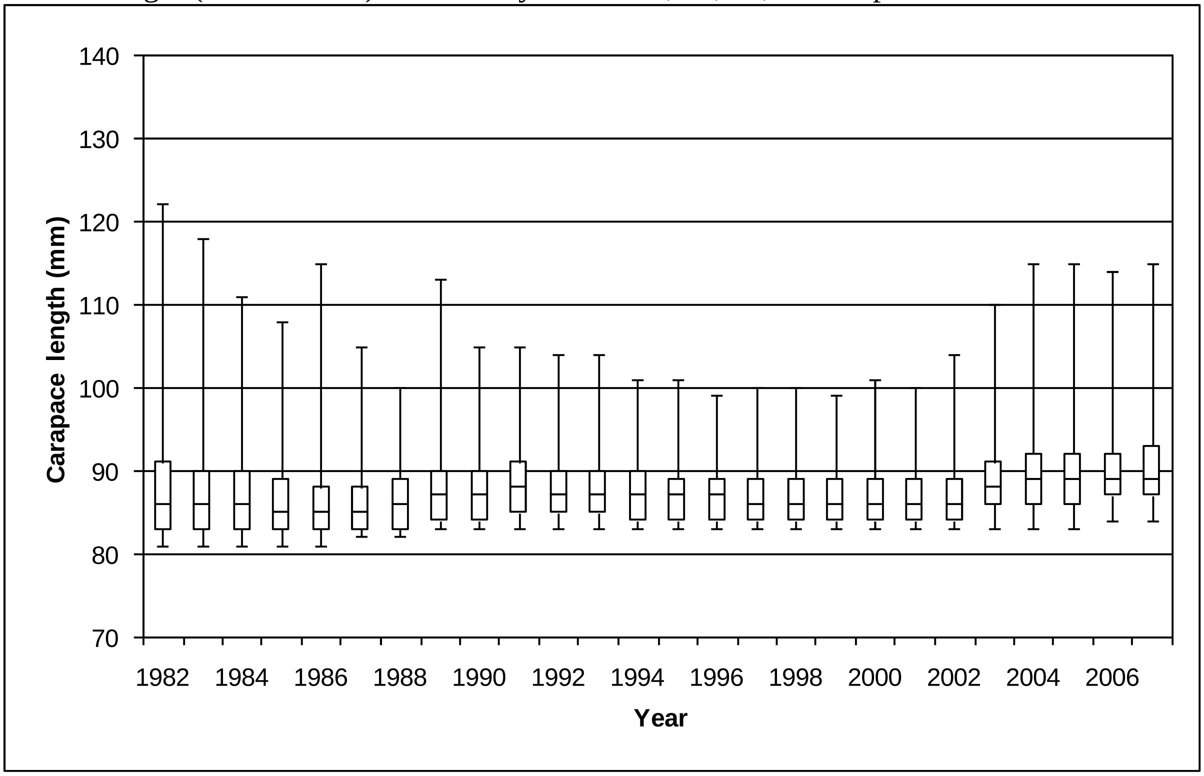


Figure 5.1.1.4.6. Southern New England commercial catch male size structure. Median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

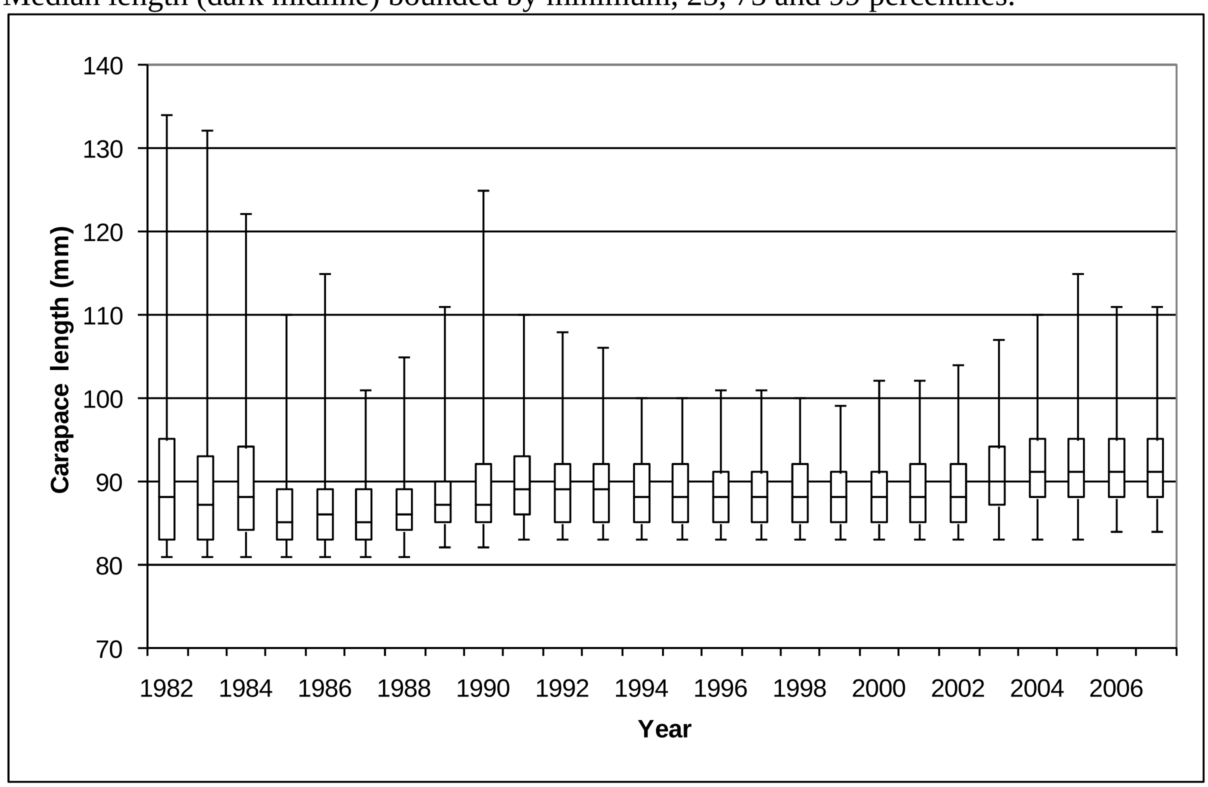
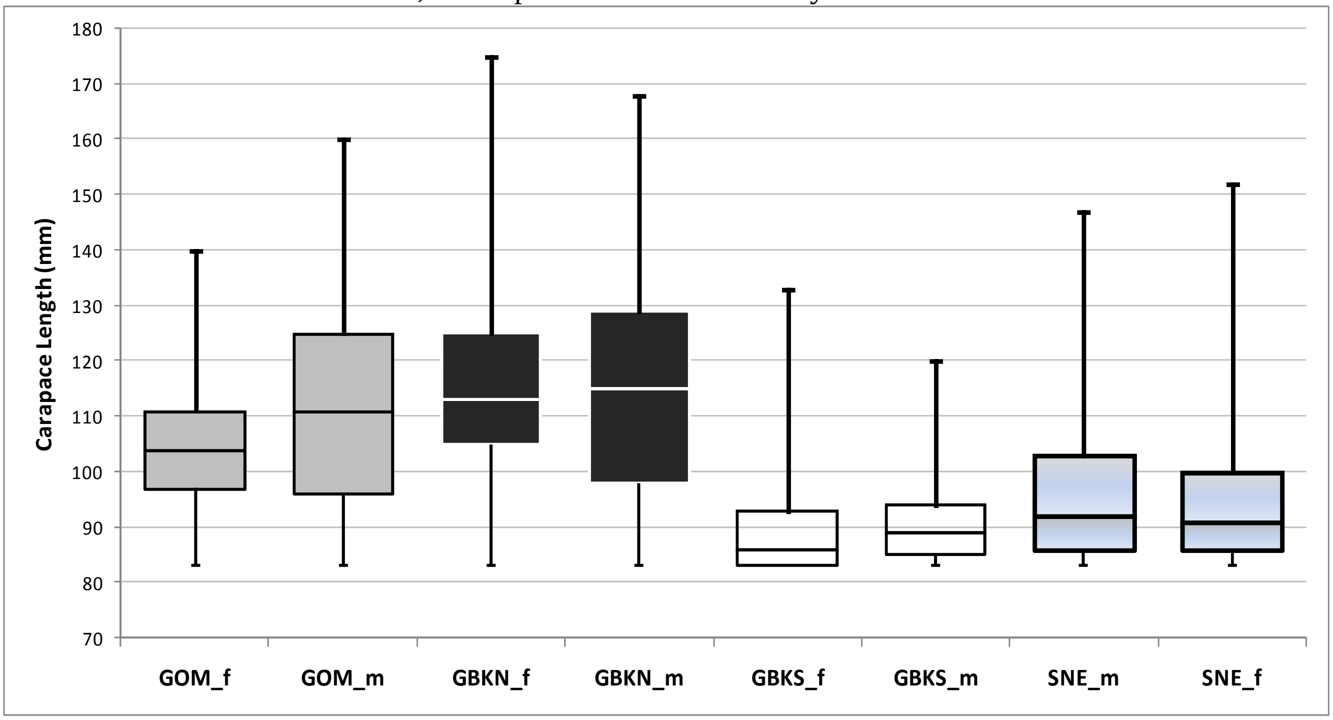


Figure 5.1.1.5.1. Length frequency of the offshore lobster catch by area and sex (females and males above 83 mm CL)
Median carapace length is bounded by the 25th and 75th percentile (boxed), 83mm minimum and 99th percentile (error bars).
Percent legal size females (non-ovigerous and not notched) are also shown for each stock and year.
Note that data are for 2002-2006, but September-December only for 2001.



GOM = Gulf of ME, Stat Area 515 (N= 8,578 females, 1,347 males)
GBK N = Georges Bank North, Stat Areas 561,562 (N= 2,831 females, 498 males)
GBK S = Georges Bank South, Stat Areas 526,543 (N= 7,116 females, 4,973 males)
SNE = Southern New England, Stat Areas 537, 616 (N= 446 females, 518 males)

Percent Females (non-eggbearing, not notched) in the Legal Size Catch

	Year:	2001*	2002	2003	2004	2005	2006
Stock	GOM	88%	88%	85%	81%	80%	80%
	GBK	58%	54%	56%	62%	57%	51%
	SNE	46%	35%				

Figure 5.1.2.2.1 Map depicting relative fishery dependent sampling intensity (# of lobster sampled/ landings) of American lobsters in North Western Atlantic NMFS Statistical reporting areas 1999 to 2003:

light gray = less than the 25th percentile; medium gray = between the 25th and 75th percentile; dark gray = greather than the 75th percentile.

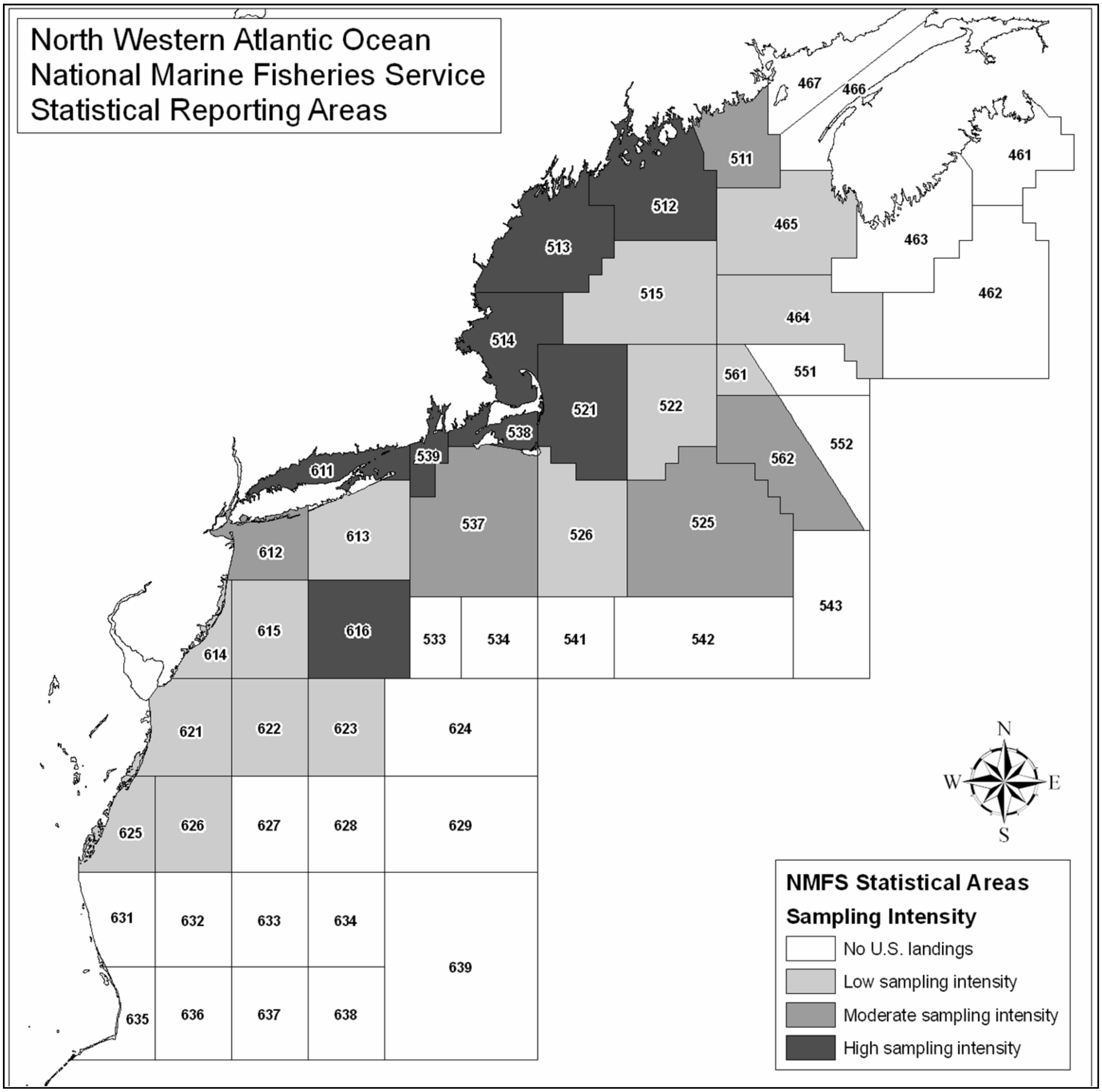


Figure 5.1.2.2.2 Map depicting relative fishery dependent sampling intensity (# of lobster sampled/ landings) of American lobsters in North Western Atlantic NMFS Statistical reporting areas 2003 to 2007:
light gray = less than the 25th percentile; medium gray = between the 25th and 75th percentile; dark gray = greater than the 75th percentile.

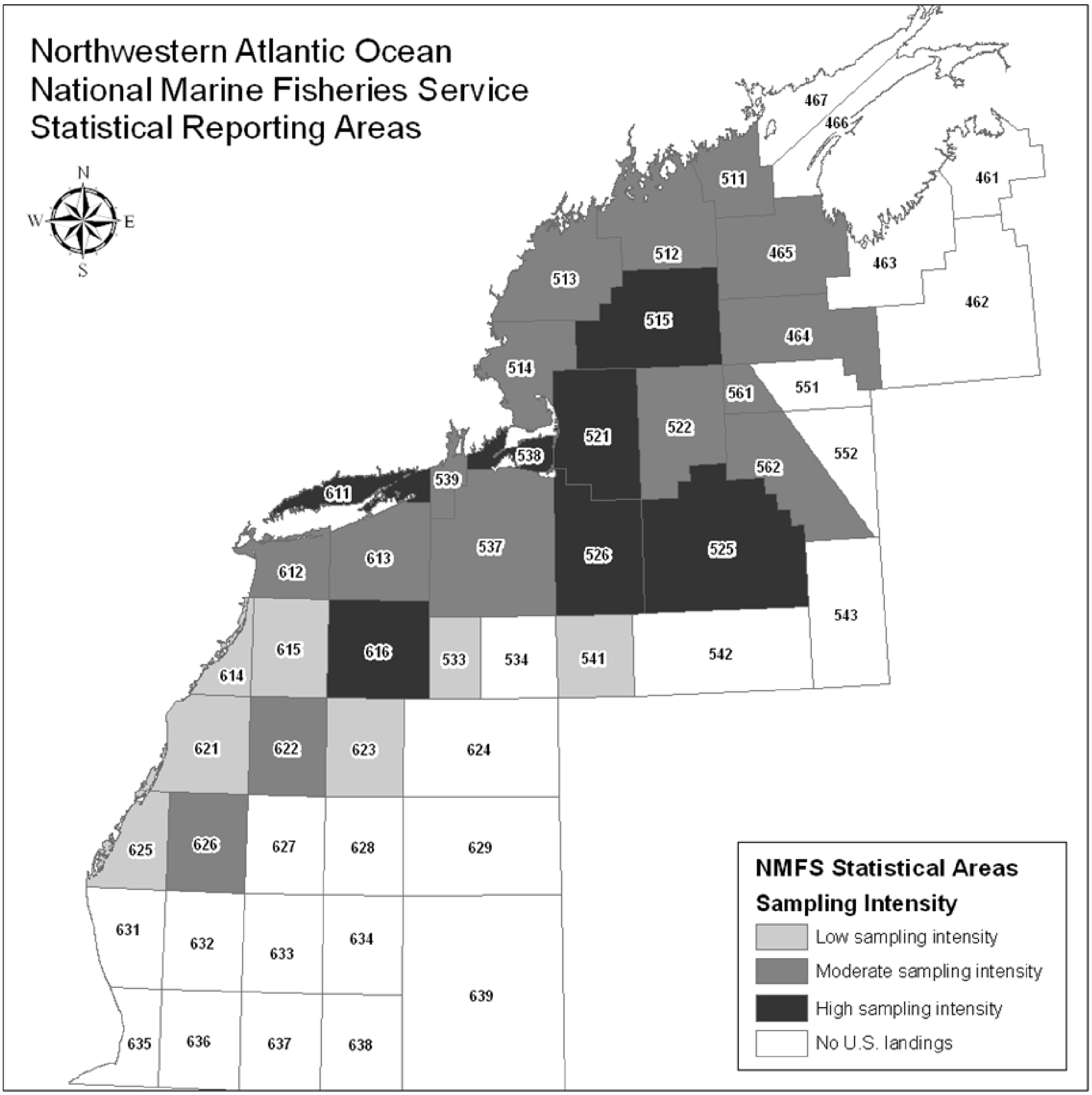


Figure 5.2.1.2.1.1. Gulf of Maine Trawl Survey Abundance Indices
Fall indices (sexes combined) are generated by the NEFSC survey in offshore GOM waters, the Maine survey in ME and NH state waters, and the Massachusetts survey in state waters north of Cape Cod.

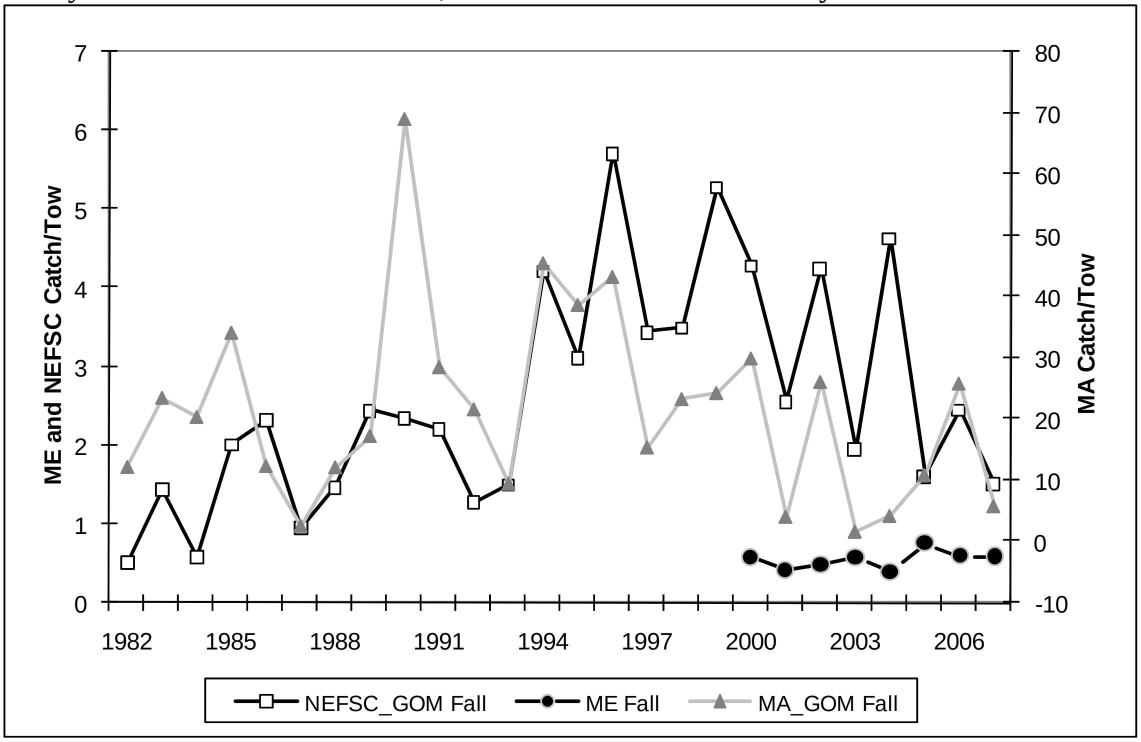


Figure 5.2.1.2.1.2. Georges Bank Trawl Survey Abundance Indices
Spring and fall indices (sexes combined) are generated by the NEFSC survey in GBK

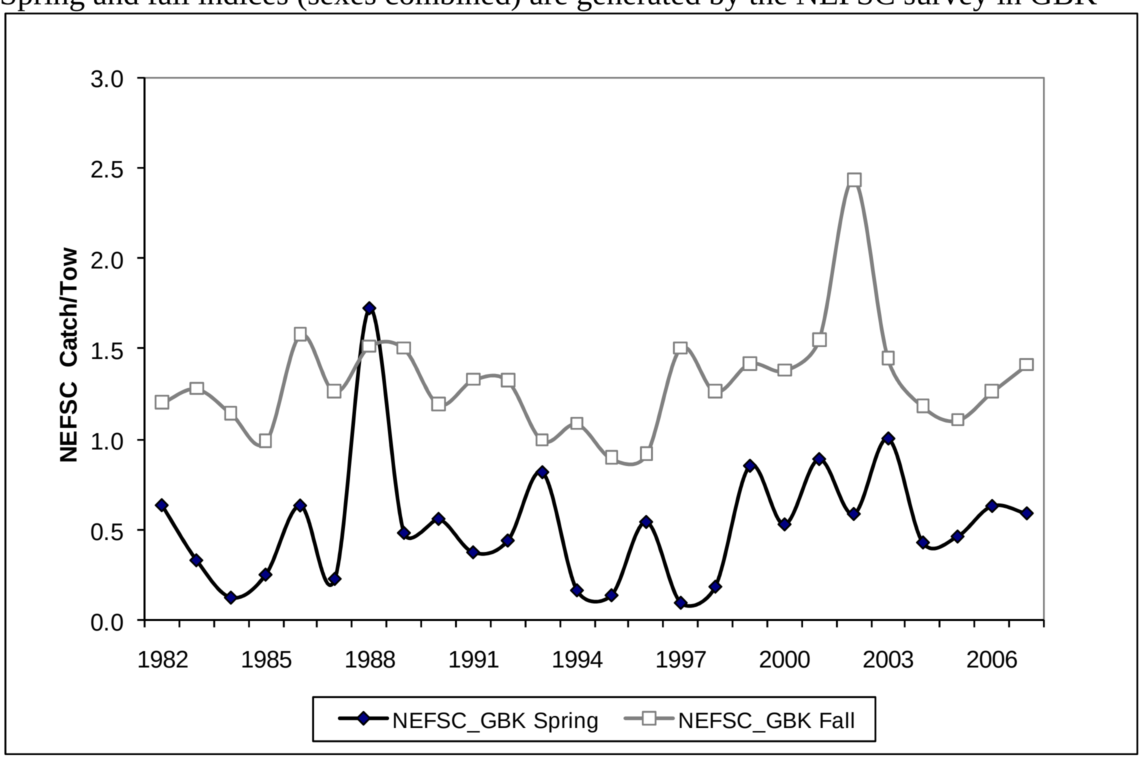


Figure 5.2.1.2.1.3. Southern New England Trawl Survey Abundance Indices
Fall indices (sexes combined) are generated by the NEFSC survey for offshore waters

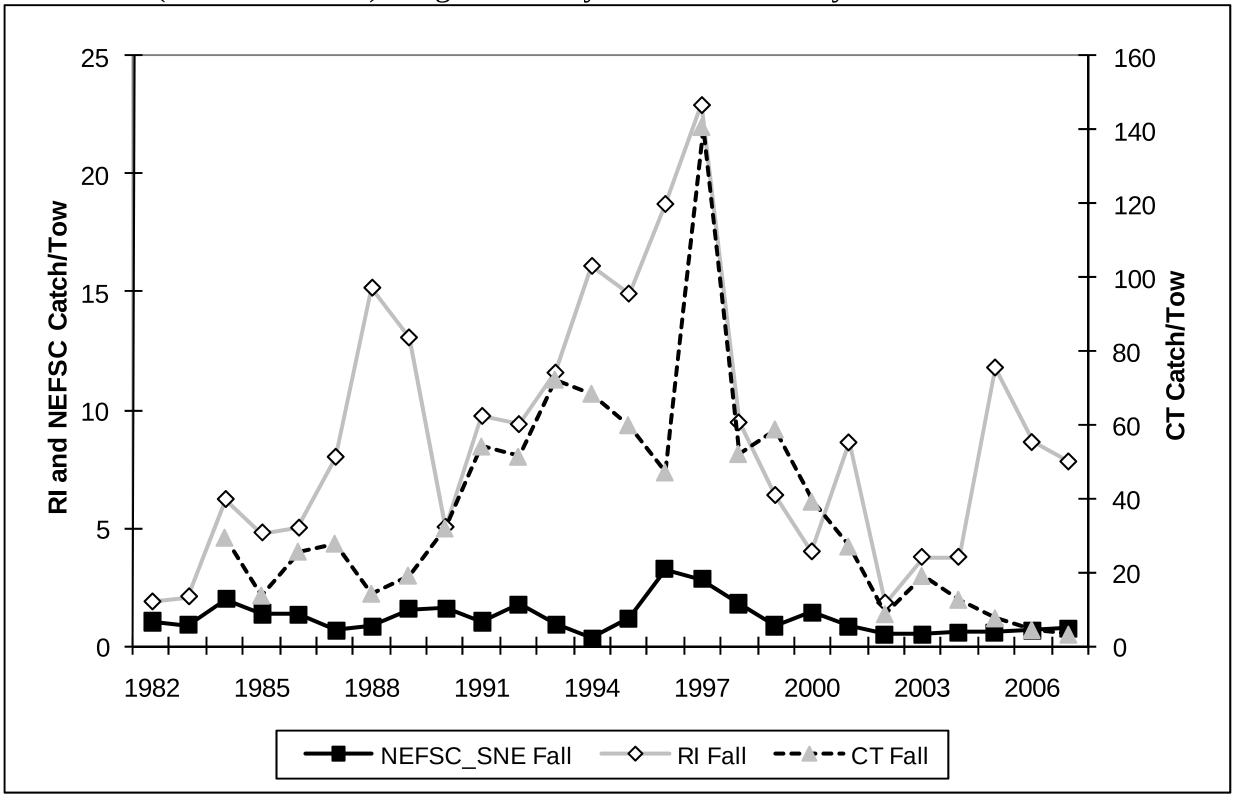


Figure 5.2.1.2.2.1. Gulf of Maine NEFSC Fall female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

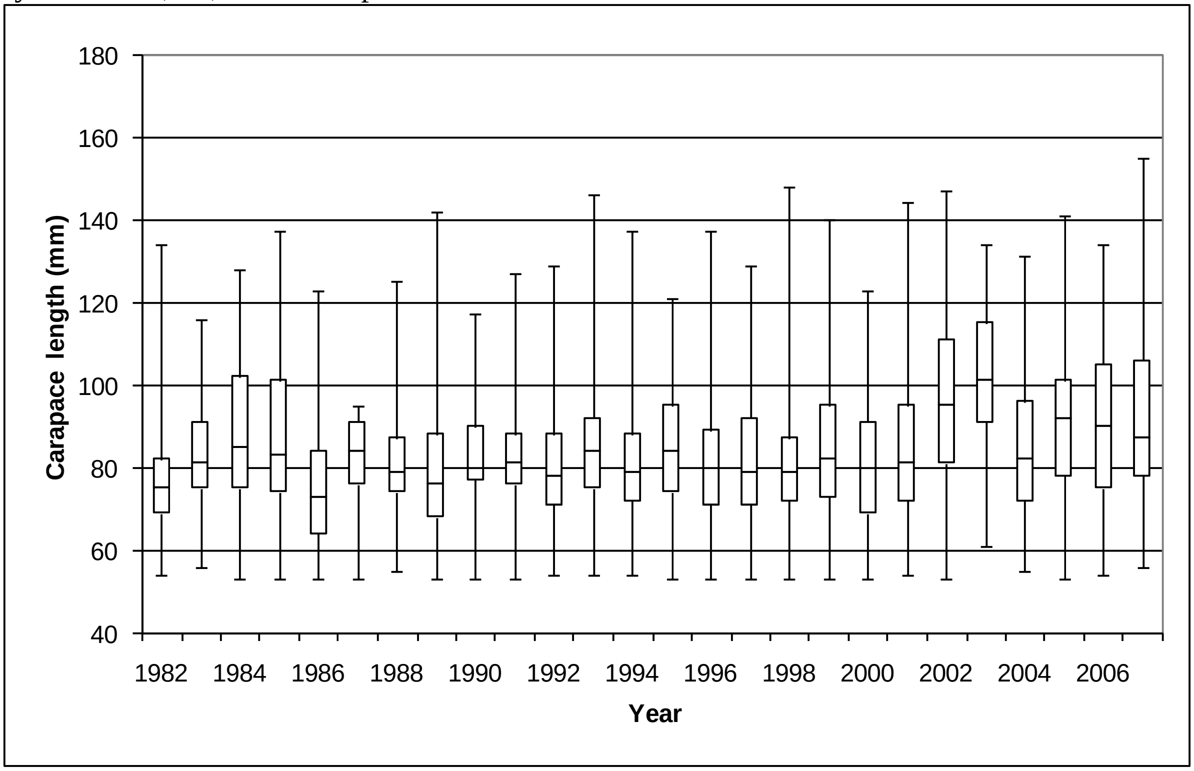


Figure 5.2.1.2.2.2. Gulf of Maine NEFSC Fall male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

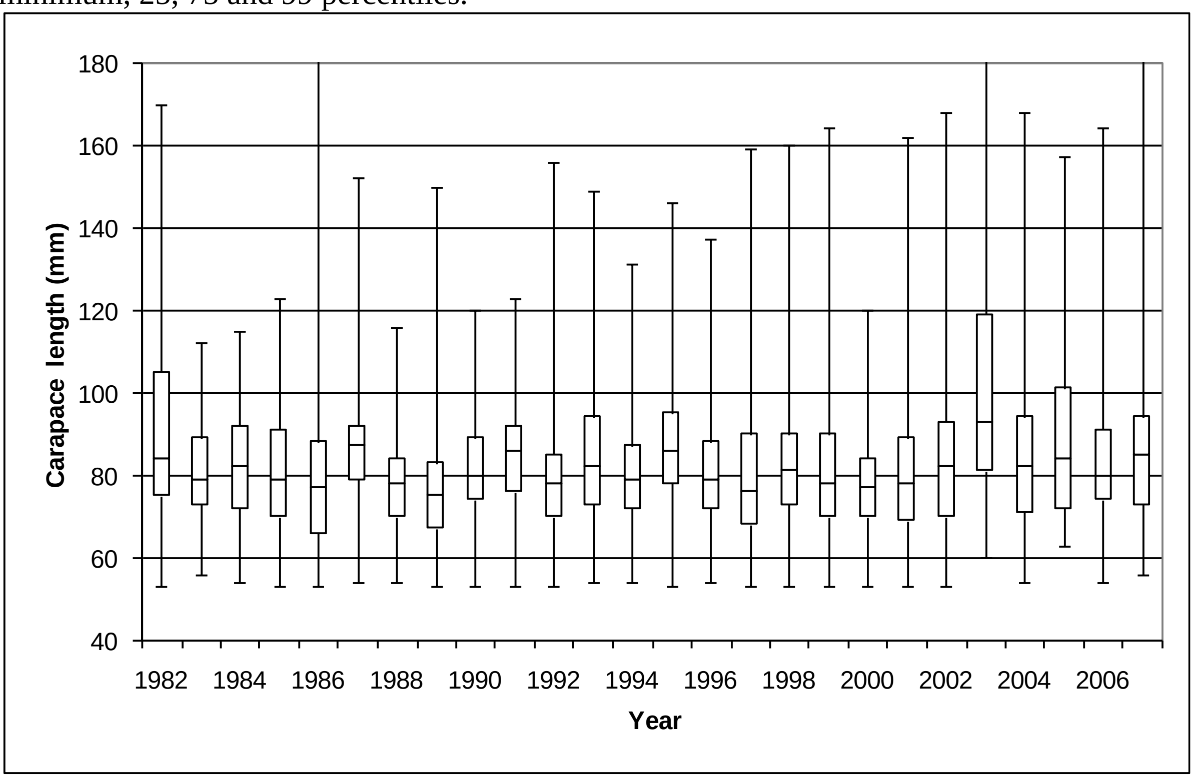


Figure 5.2.1.2.2.3. Gulf of Maine ME Fall Survey female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

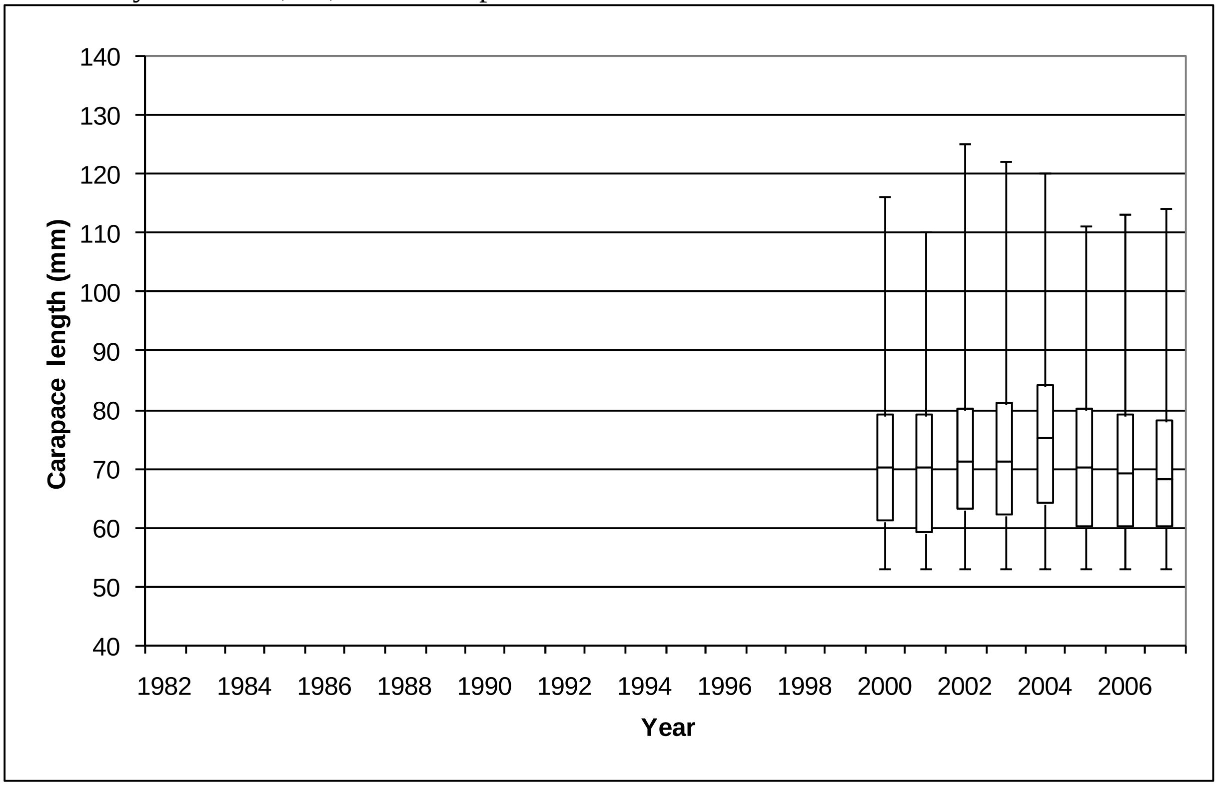


Figure 5.2.1.2.2.4. Gulf of Maine ME Fall Survey male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

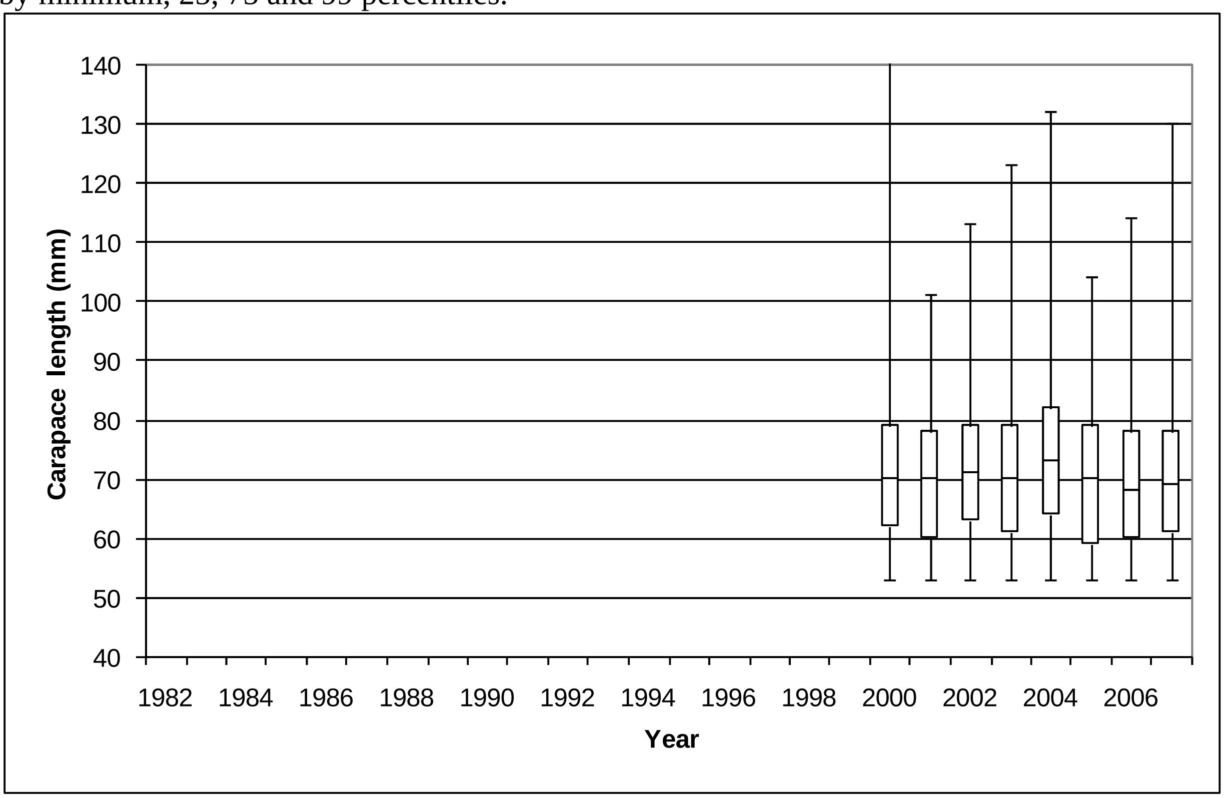


Figure 5.2.1.2.2.5. Gulf of Maine MA Fall female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

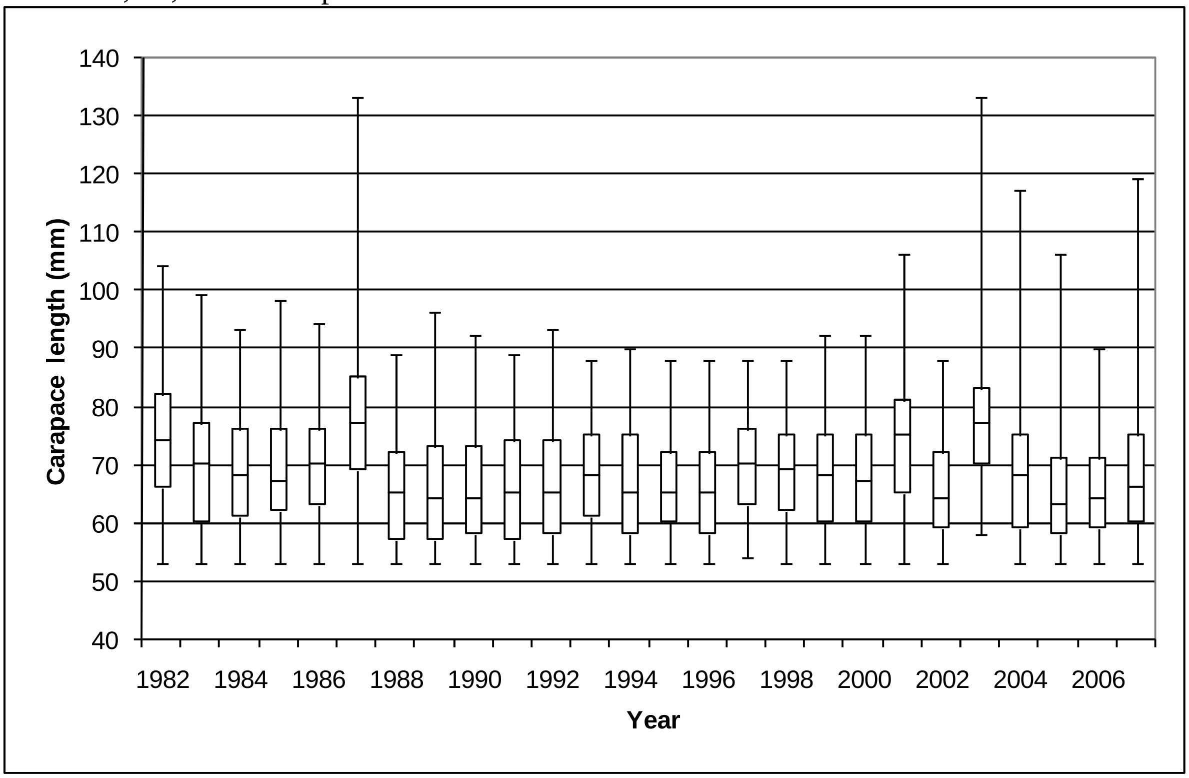


Figure 5.2.1.2.2.6. Gulf of Maine MA Fall Survey male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

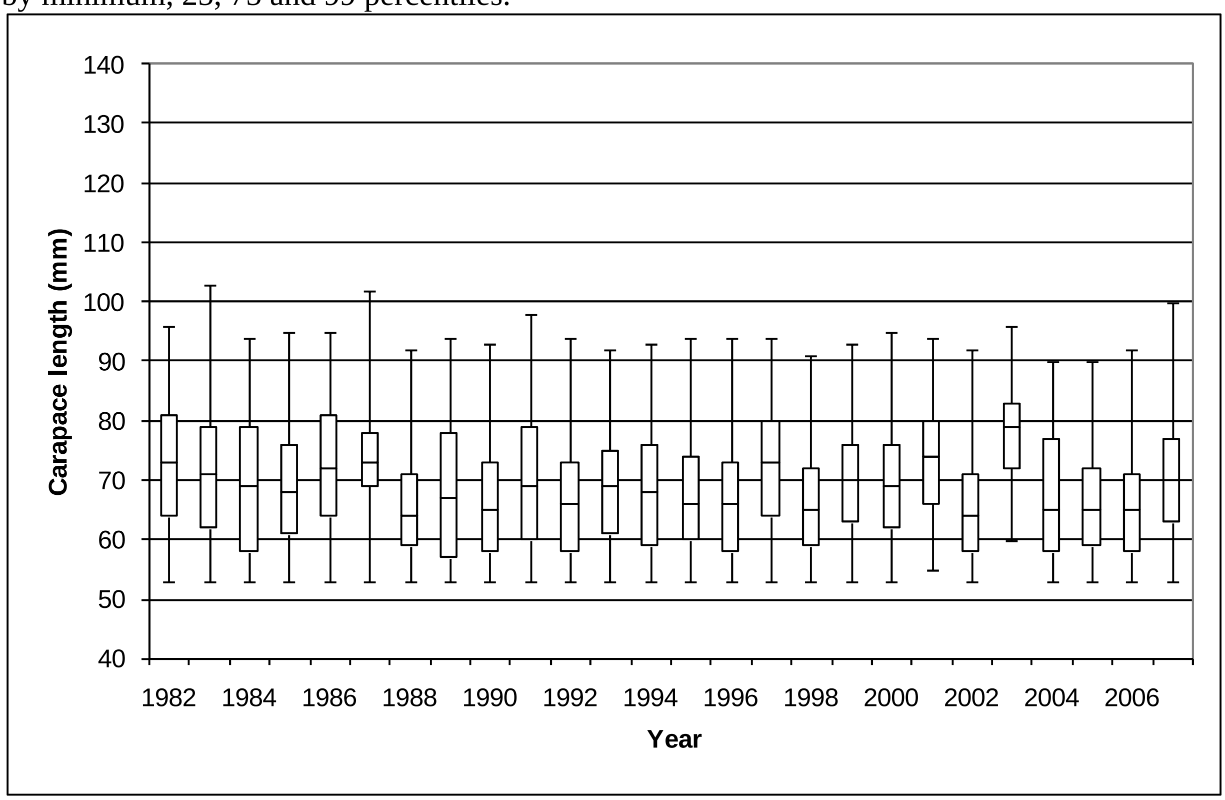


Figure 5.2.1.2.2.7. Georges Bank NEFSC Fall Survey female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

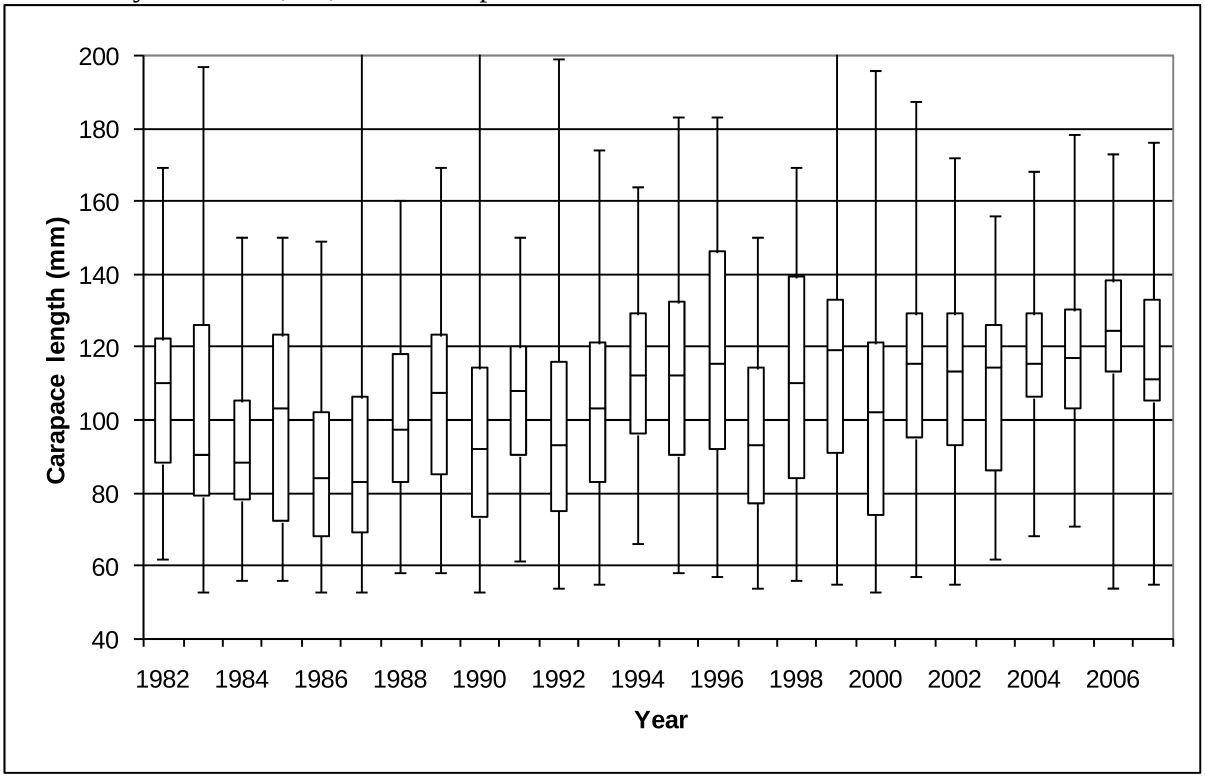


Figure 5.2.1.2.2.8. Georges Bank NEFSC Fall Survey male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

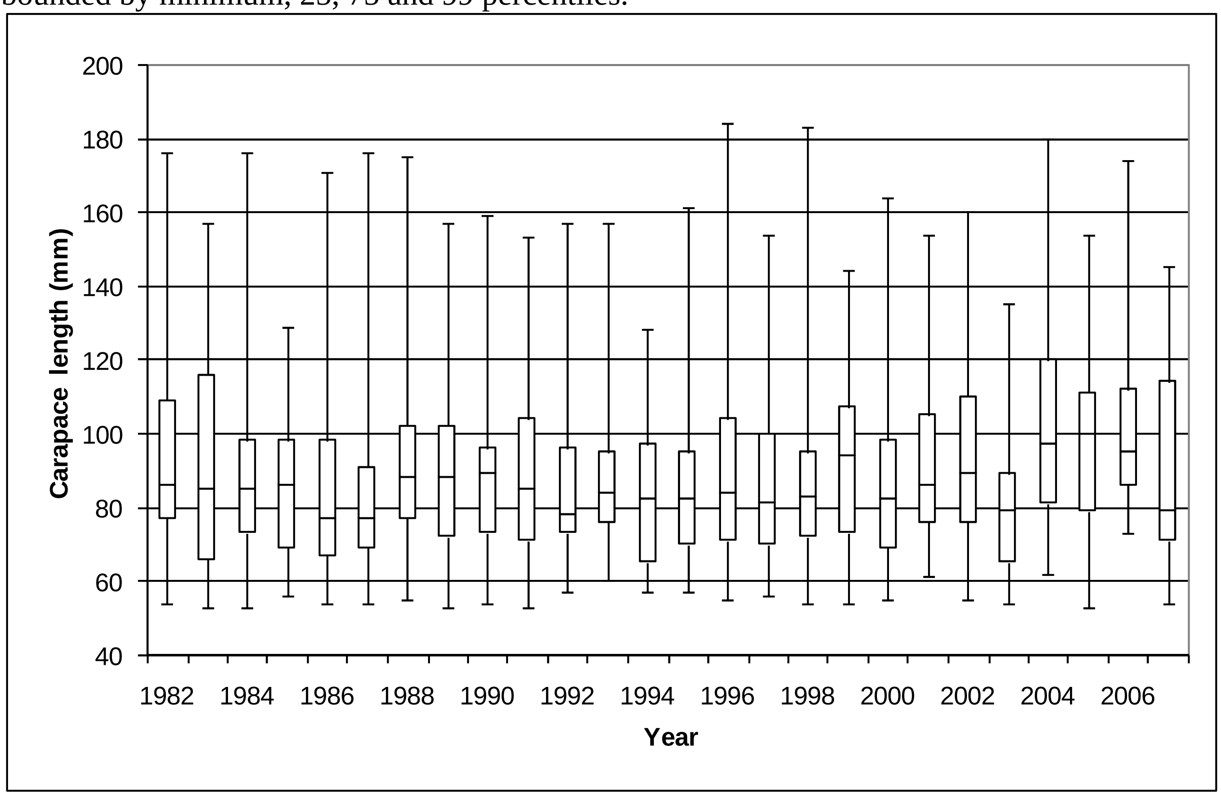


Figure 5.2.1.2.2.9. Georges Bank NEFSC Spring Survey female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

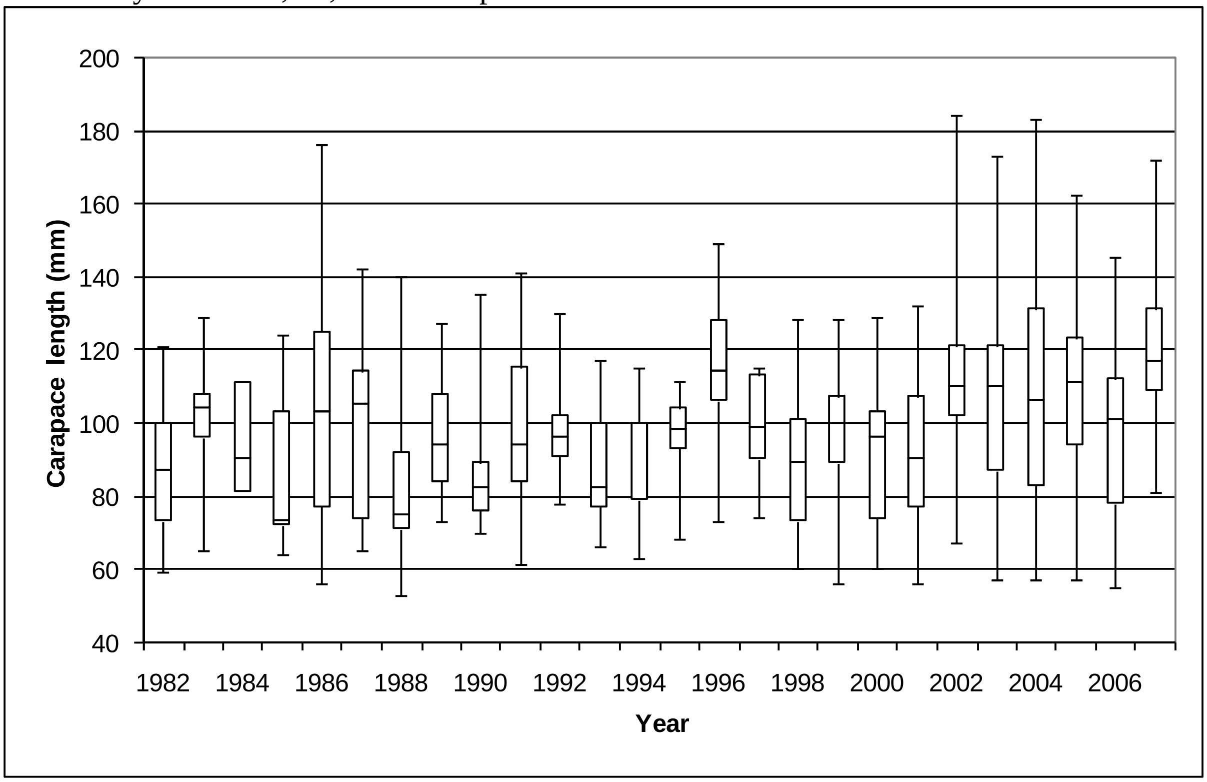


Figure 5.2.1.2.2.10. Georges Bank NEFSC Spring Survey male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

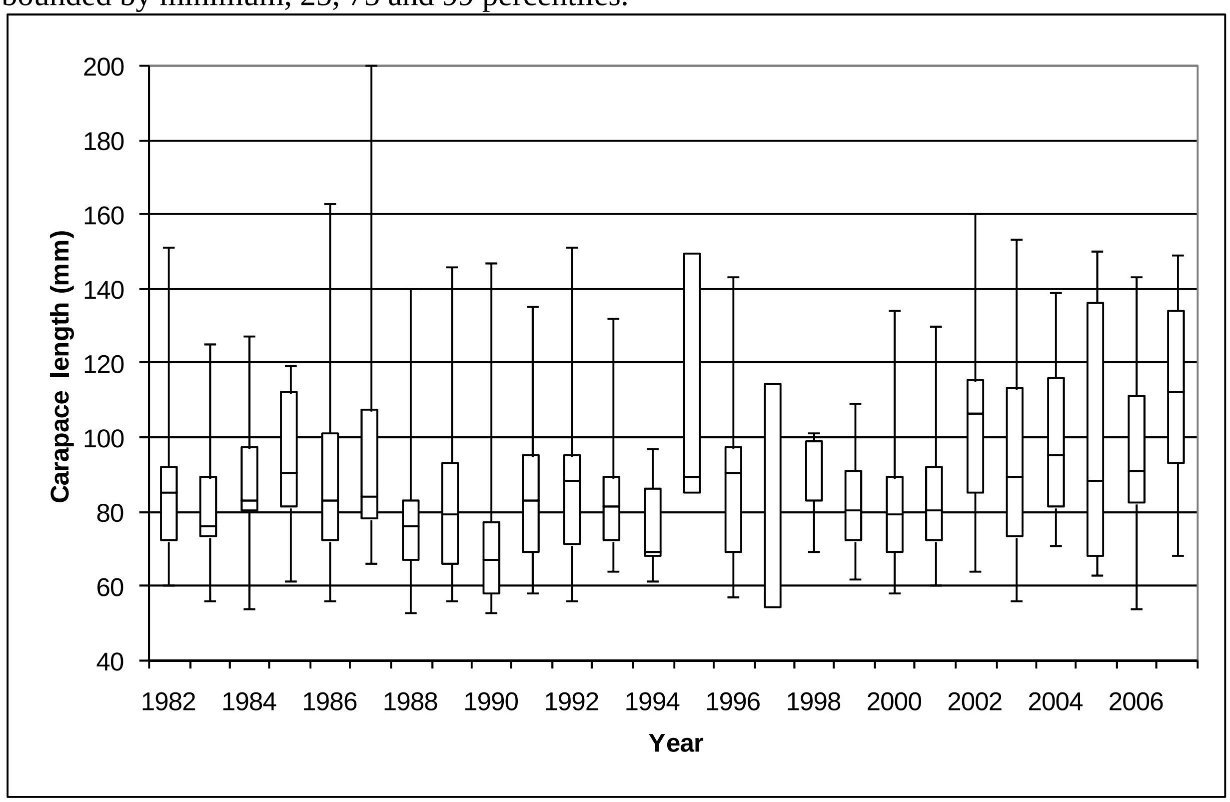


Figure 5.2.1.2.2.11. Southern New England NEFSC Fall Survey female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

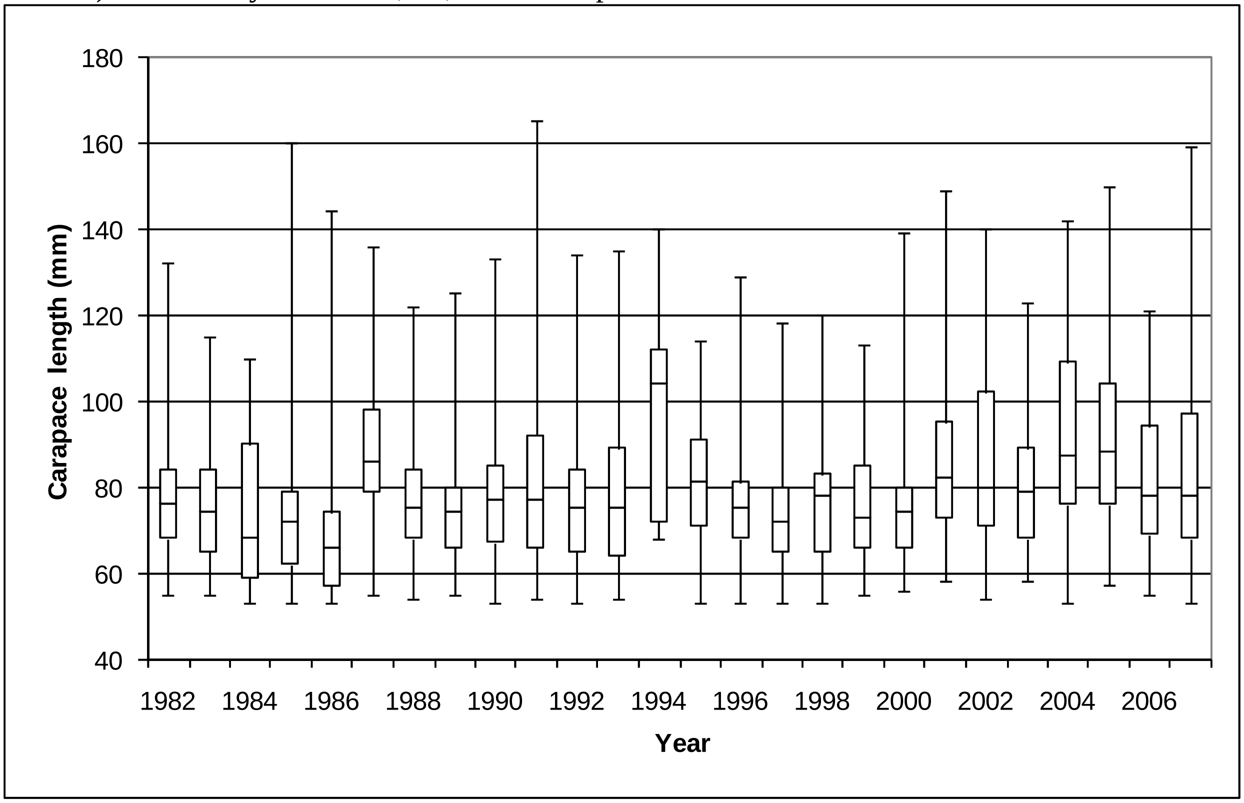


Figure 5.2.1.2.2.12. Southern New England NEFSC Fall Survey male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

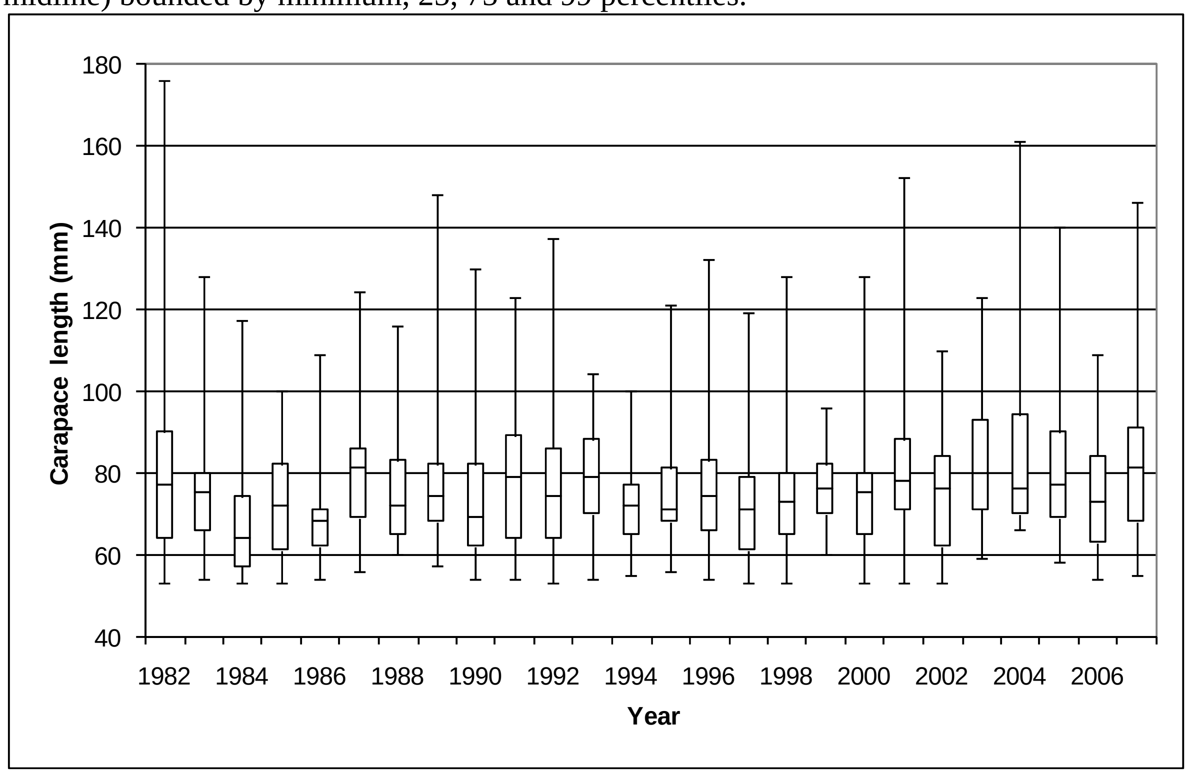


Figure 5.2.1.2.2.13. Southern New England CT Fall female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

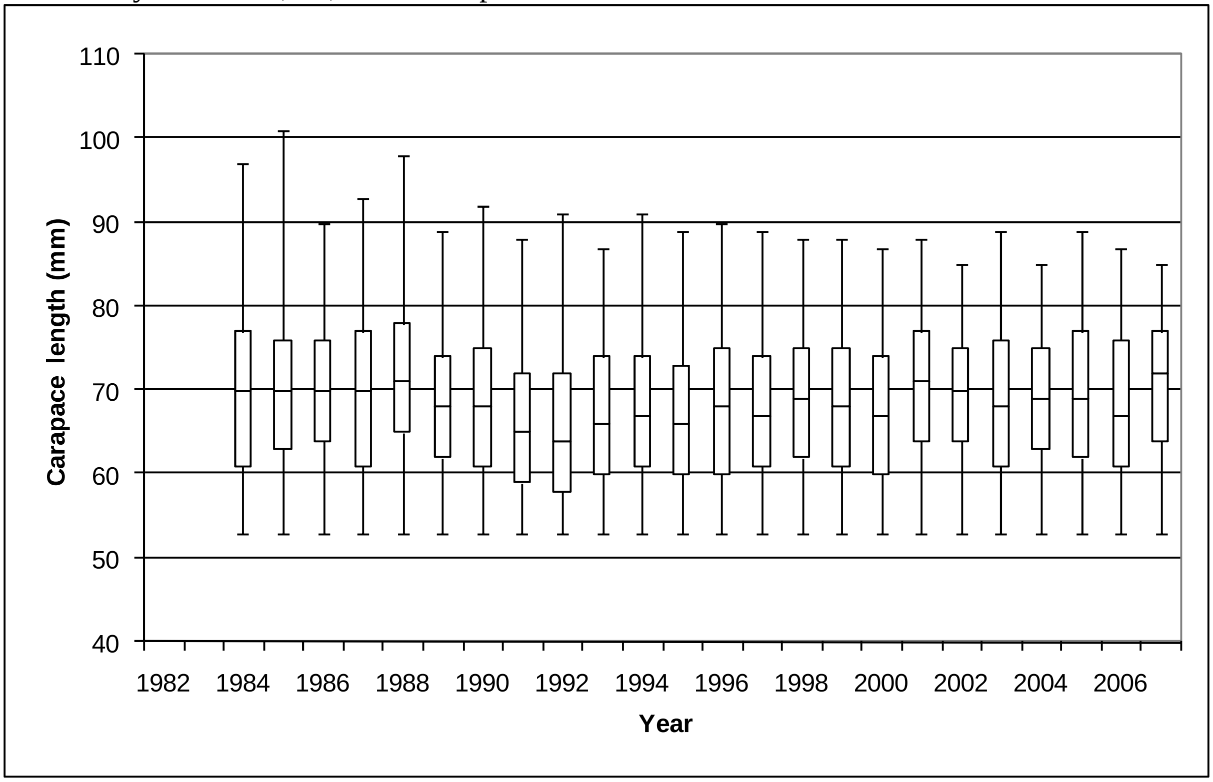


Figure 5.2.1.2.2.14. Southern New England CT Fall male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

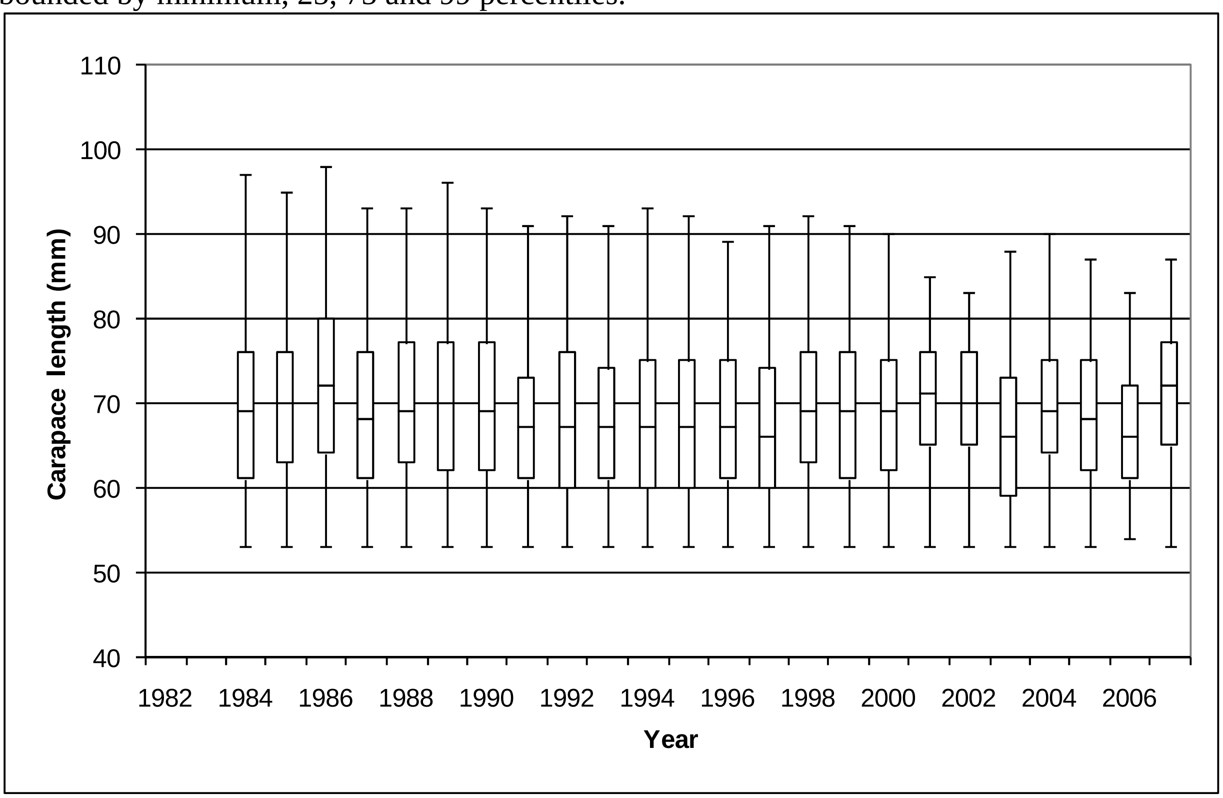


Figure 5.2.1.2.2.15. Southern New England RI Fall Survey female lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

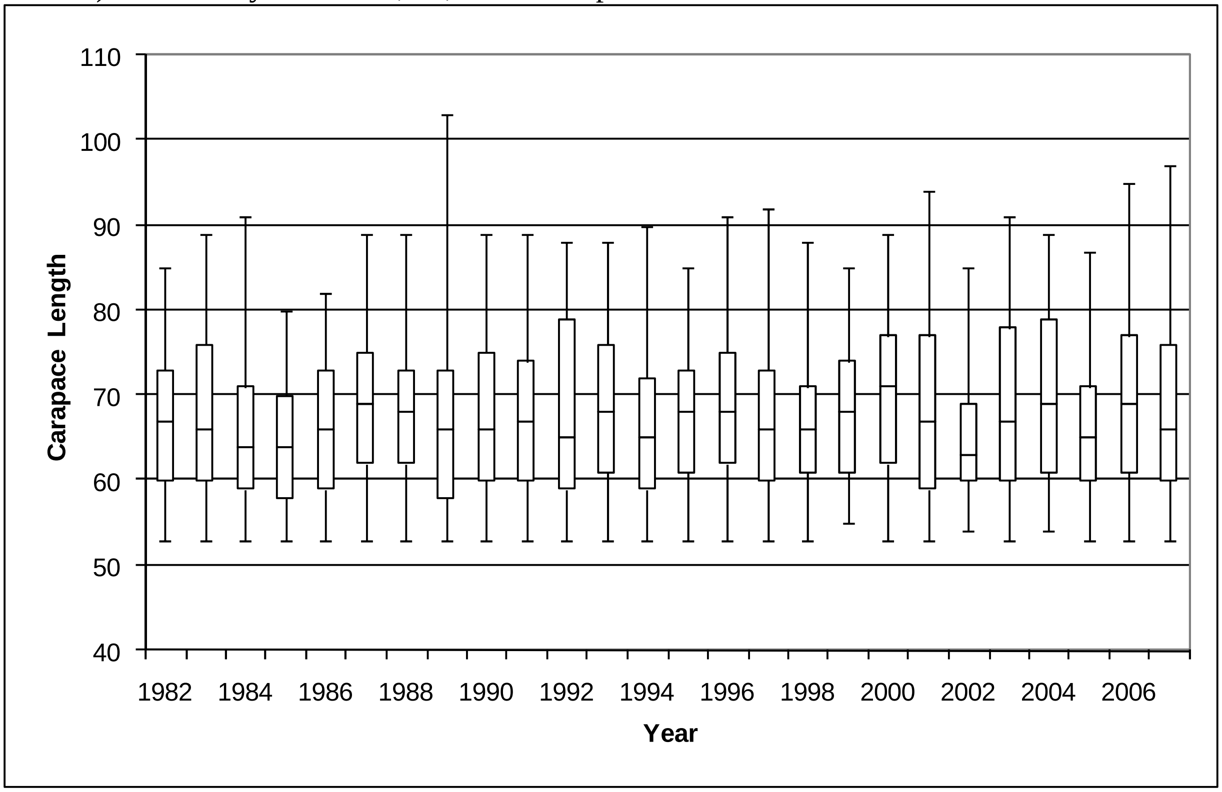


Figure 5.2.1.2.2.16. Southern New England RI Fall Survey male lobster median length (dark midline) bounded by minimum, 25, 75 and 99 percentiles.

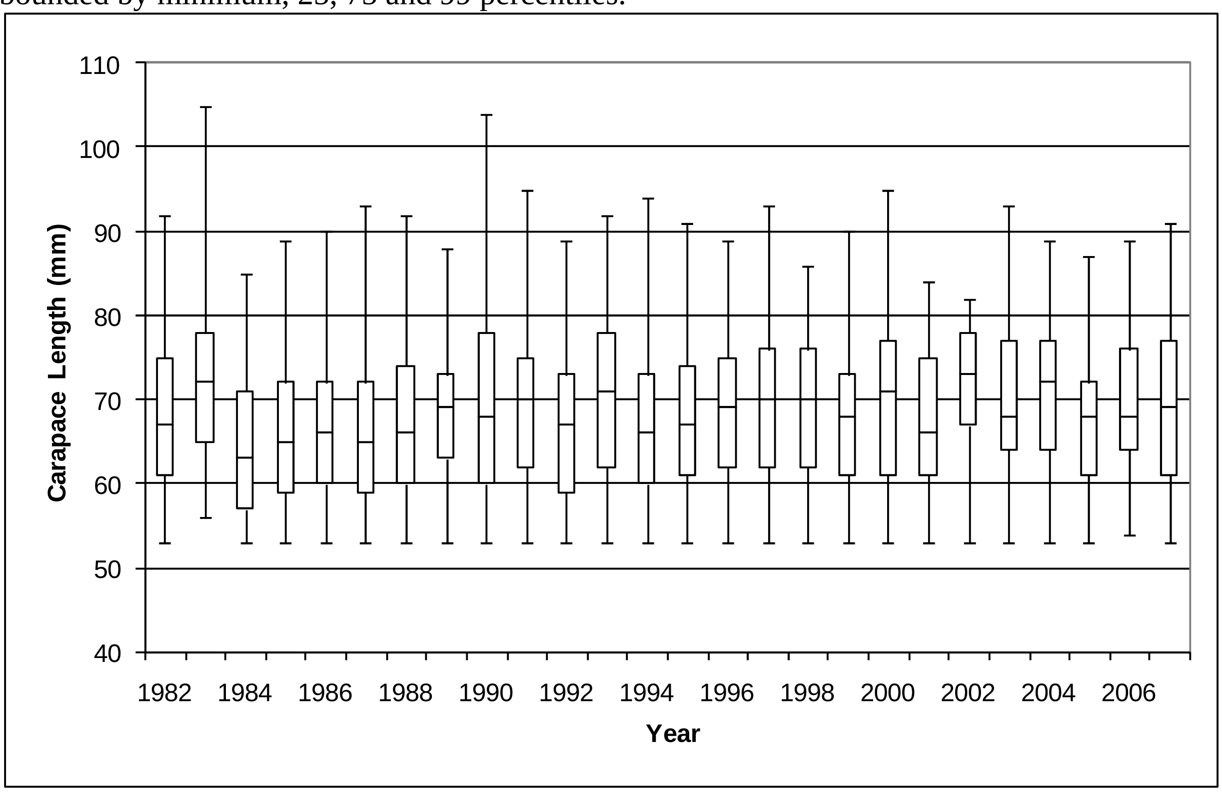


Figure 5.2.2.2.1. Percent of the catch at length for all ventless trap survey areas (combined) in the Gulf of Maine stock unit, 2006 and 2007.
Vertical lines represent minimum legal size (3 ¼", 82.55 mm, dashed) and maximum size (5", 127 mm, dotted).

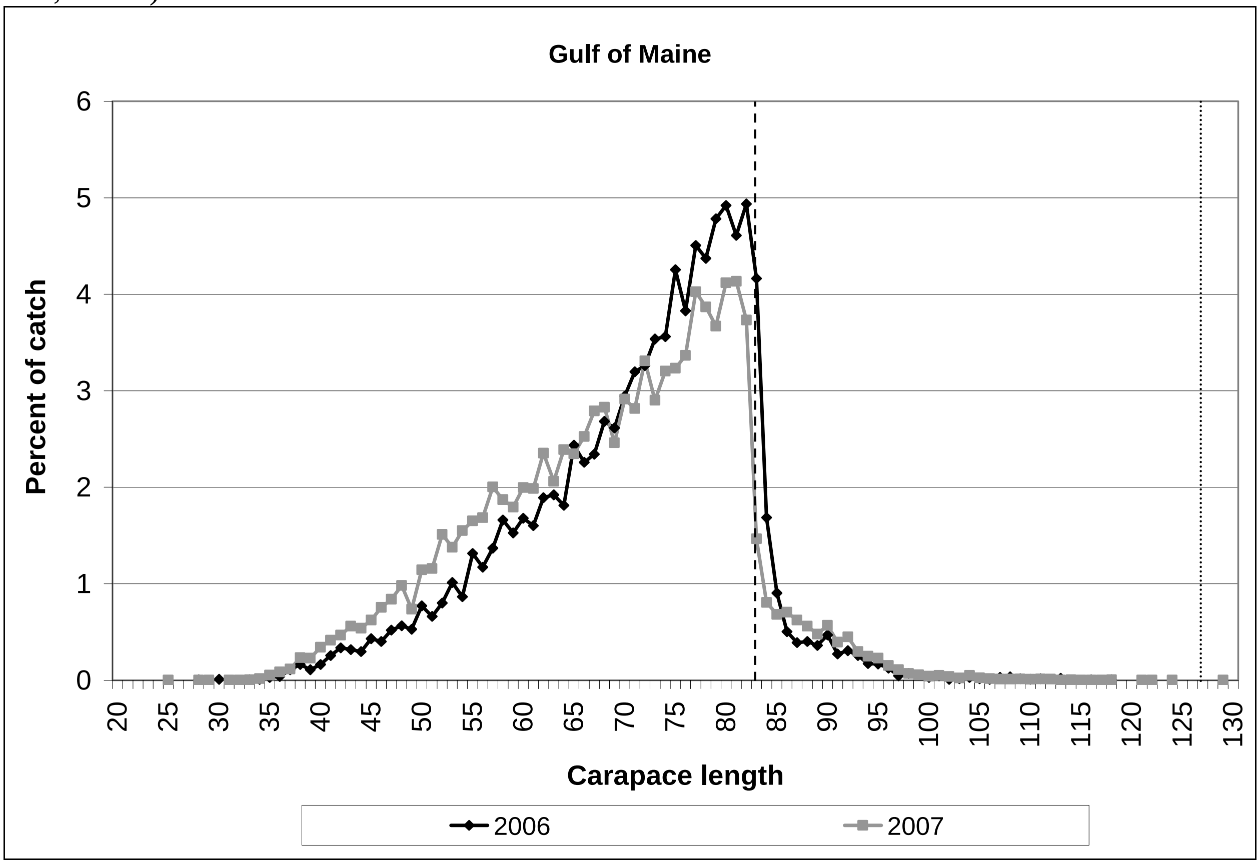


Figure 5.2.2.2.2. 2006 Gulf of Maine ventless trap survey mean catch per trap haul of legal lobster at each sampling station. Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

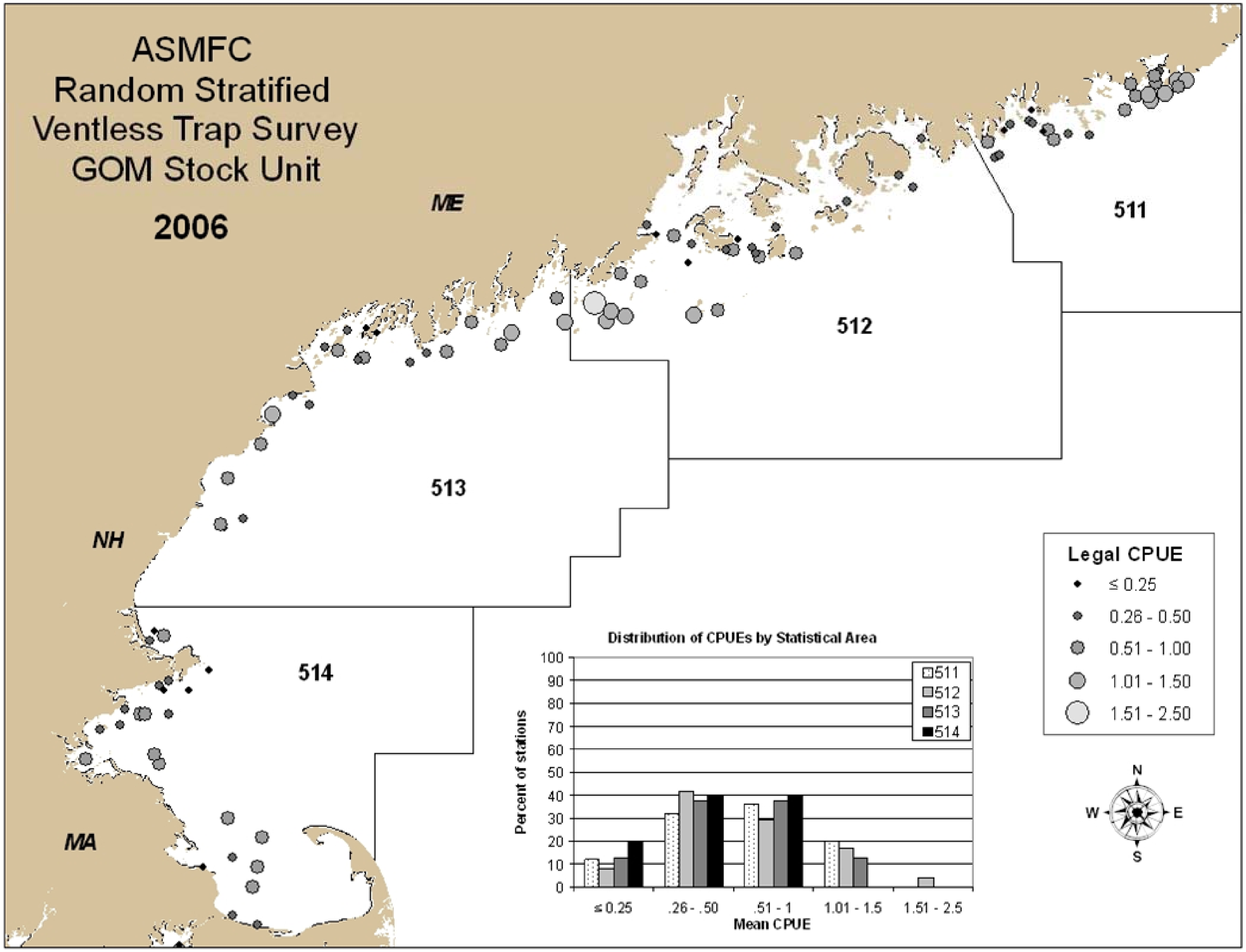


Figure 5.2.2.2.3. 2007 Gulf of Maine ventless trap survey mean catch per trap haul of legal lobster at each sampling station. Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

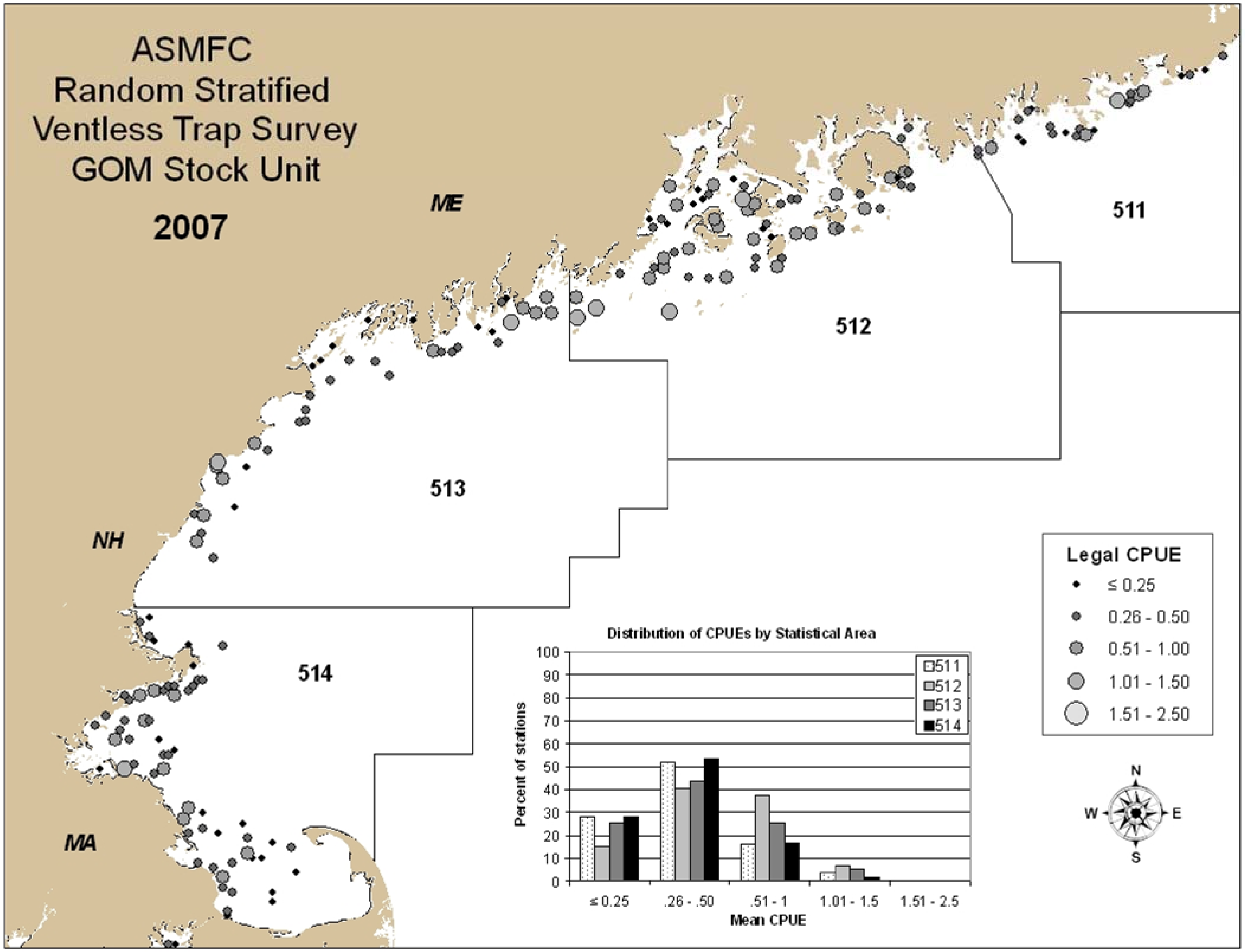


Figure 5.2.2.2.4. Mean catch per trap haul of sublegal lobster at each sampling station in the 2006 Gulf of Maine ventless trap survey. Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

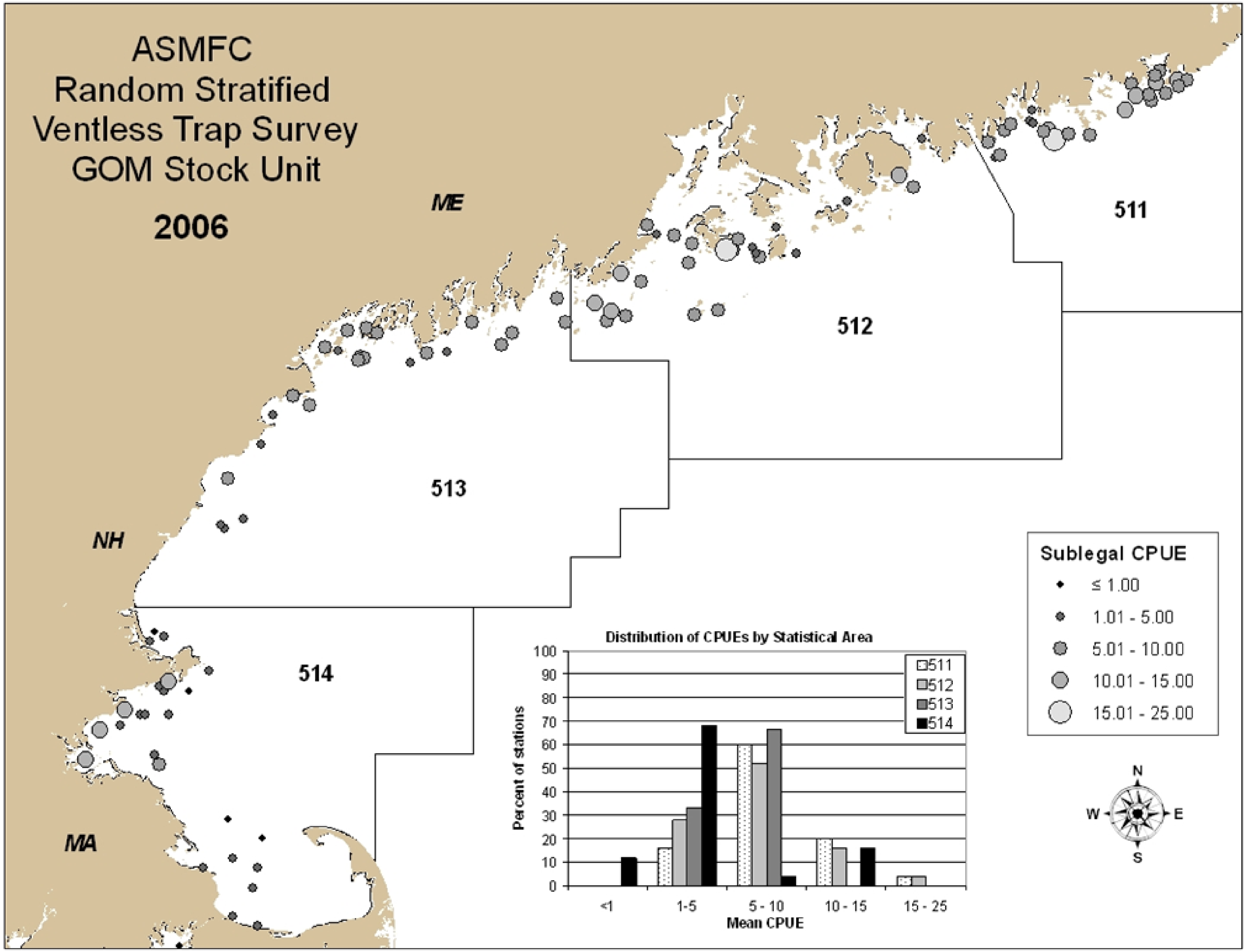


Figure 5.2.2.2.5. Mean catch per trap haul of sublegal lobster at each sampling station in the 2007 Gulf of Maine ventless trap survey. Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

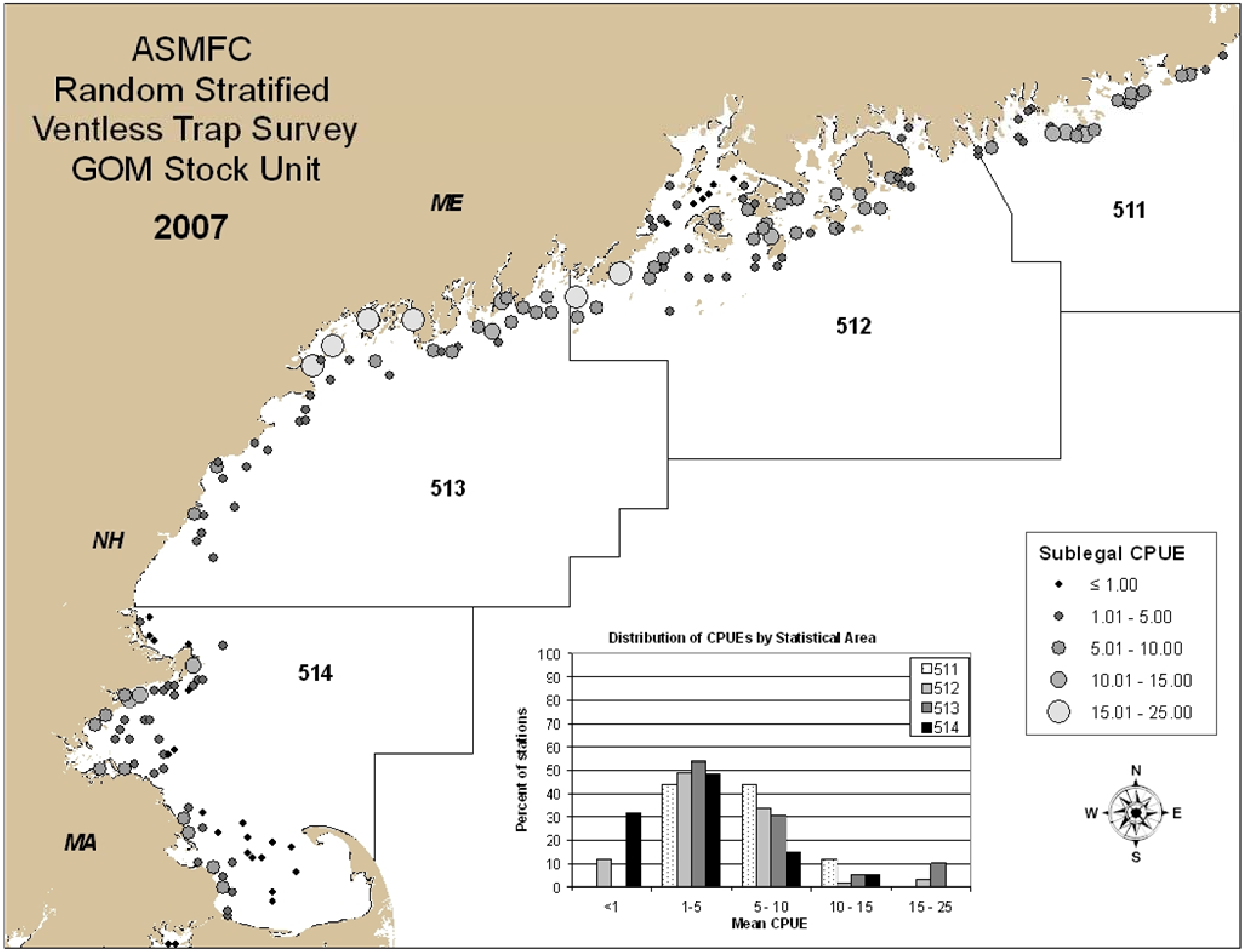


Figure 5.2.2.2.6. Percent of the catch at length for all ventless trap survey areas (combined) in the Southern New England stock unit, 2006 and 2007.

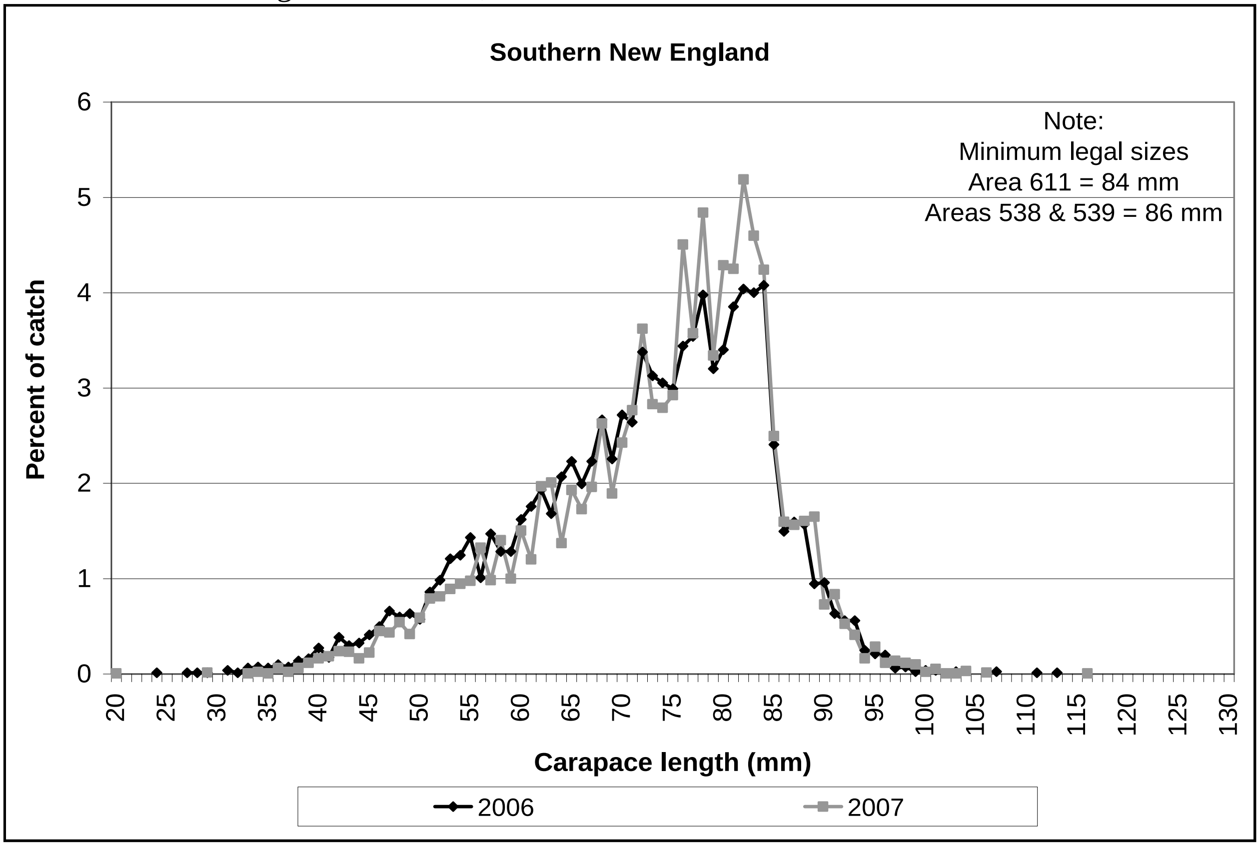


Figure 5.2.2.2.7. Mean catch per trap haul of legal lobster at each sampling station in the 2006 Southern New England ventless trap survey.
Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

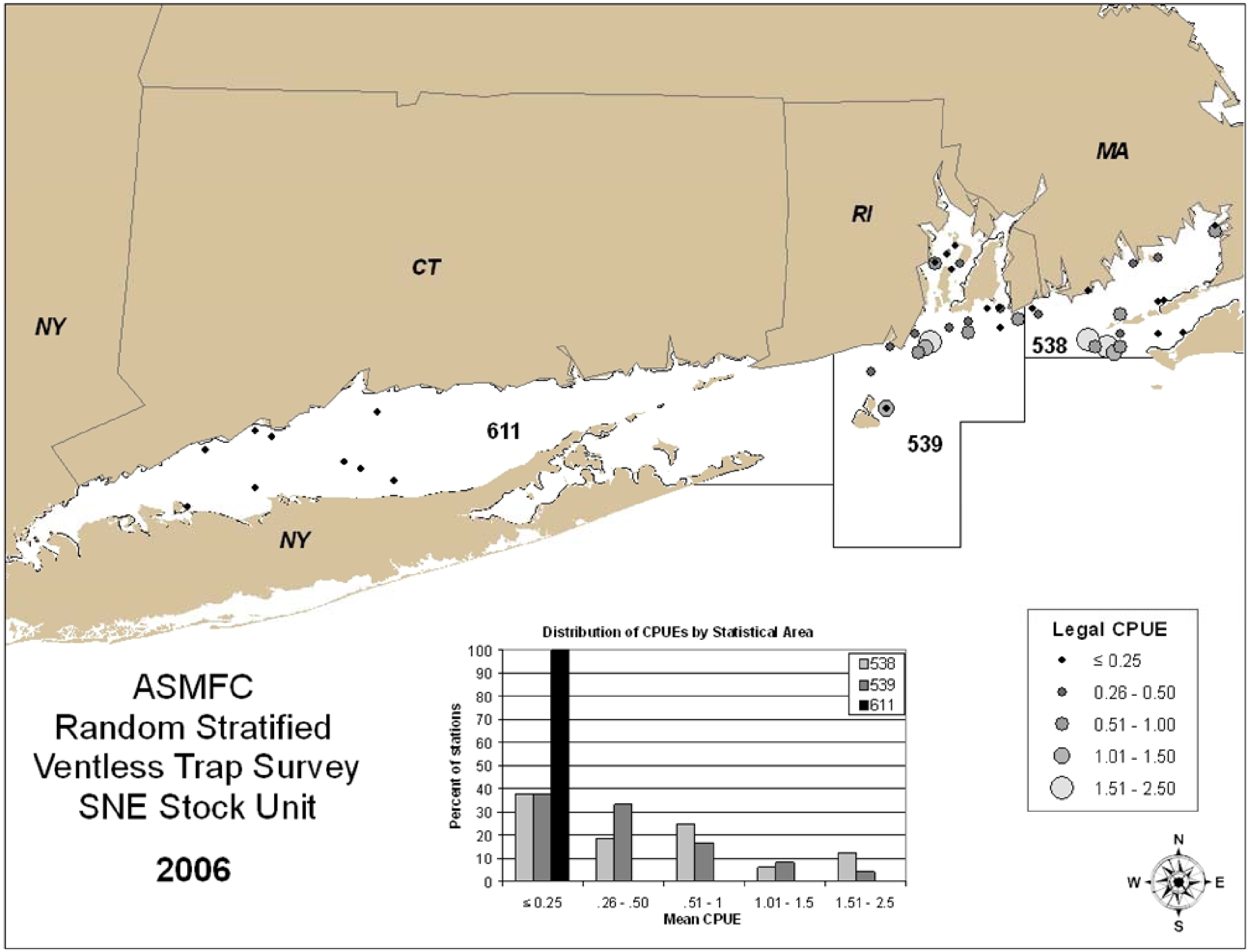


Figure 5.2.2.2.8. Mean catch per trap haul of legal lobster at each sampling station in the 2007 Southern New England ventless trap survey.
Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

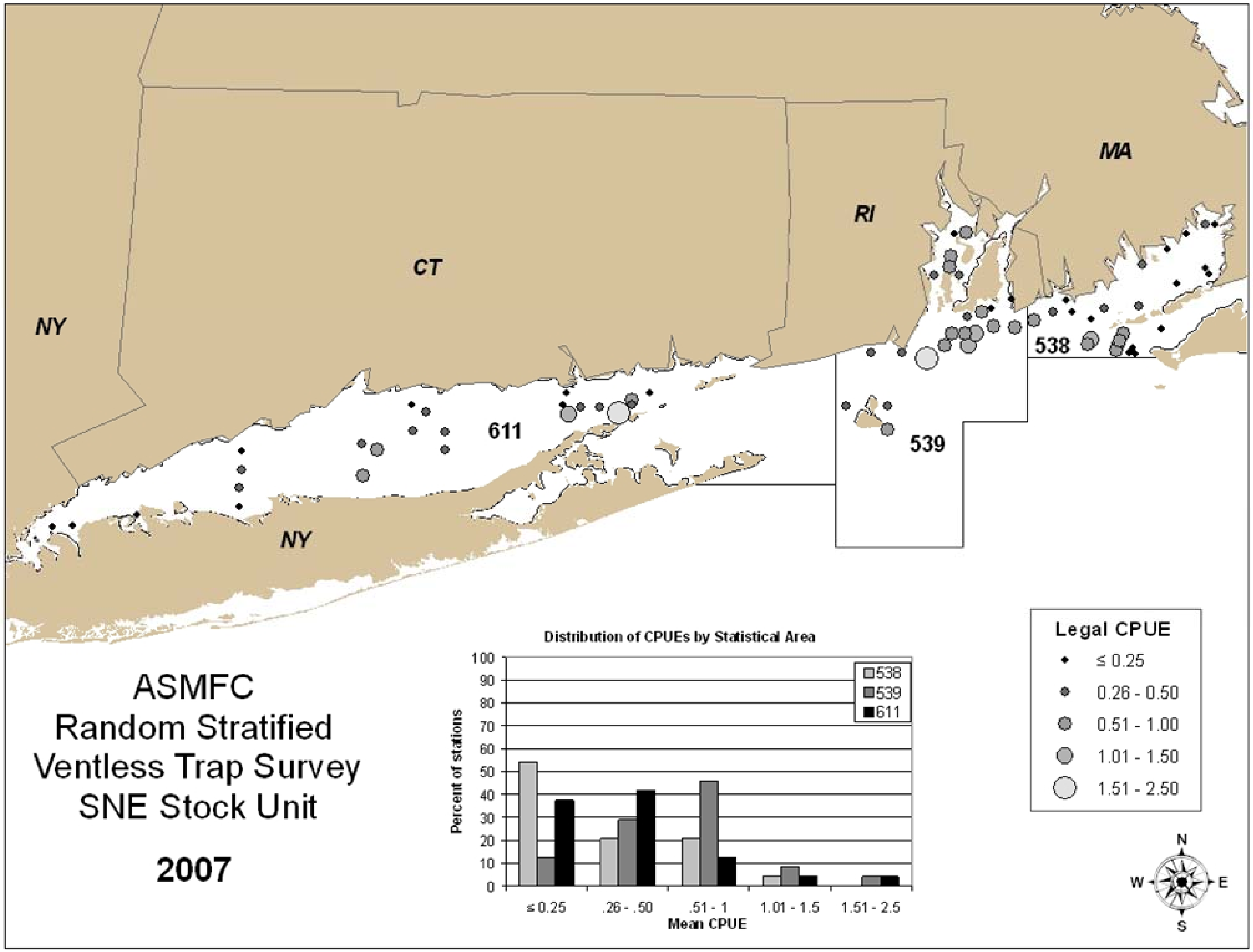


Figure 5.2.2.2.9. Mean catch per trap haul of sublegal lobster at each sampling station in the 2006 Southern New England ventless trap survey.
Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

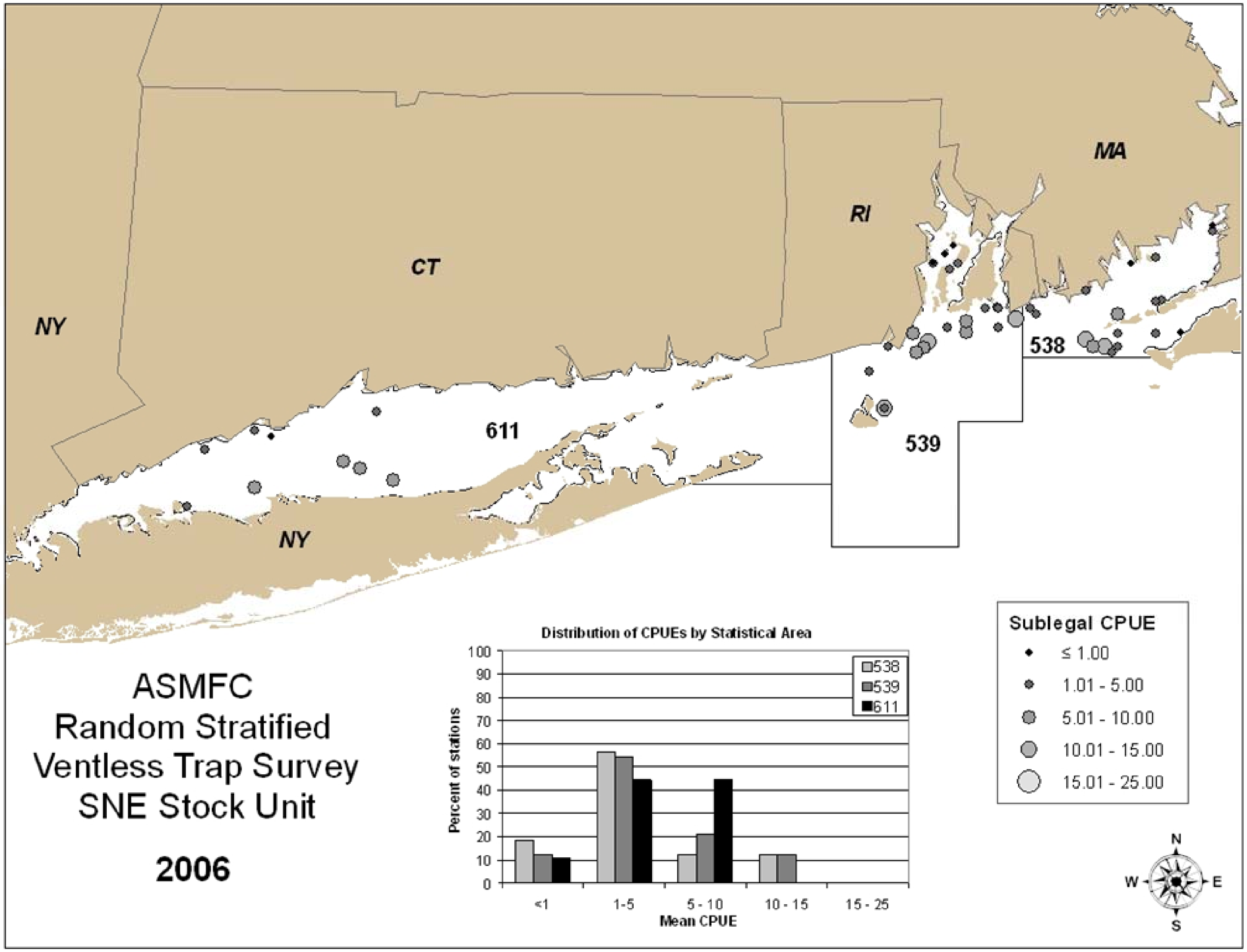


Figure 5.2.2.2.10. Mean catch per trap haul of sublegal lobster at each sampling station in the 2007 Southern New England ventless trap survey.
Graph inset depicts the percent of sampling stations in each CPUE bin by Statistical Area.

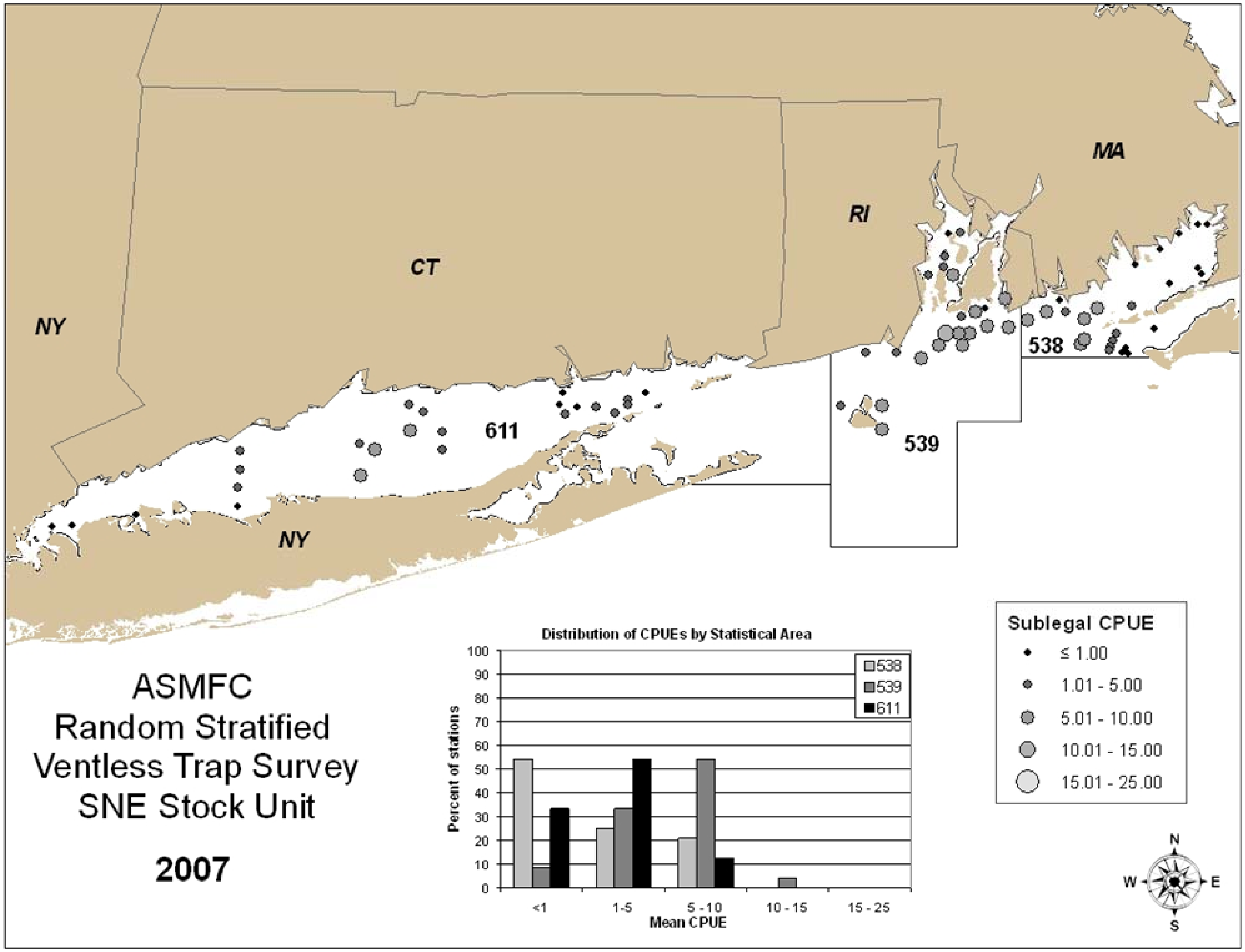


Figure 6.2.1. Effective exploitation (line with dark symbols) and fully recruited fishing mortality (full *F*, plain line with no symbols) during 1982-2007 from basecase models.

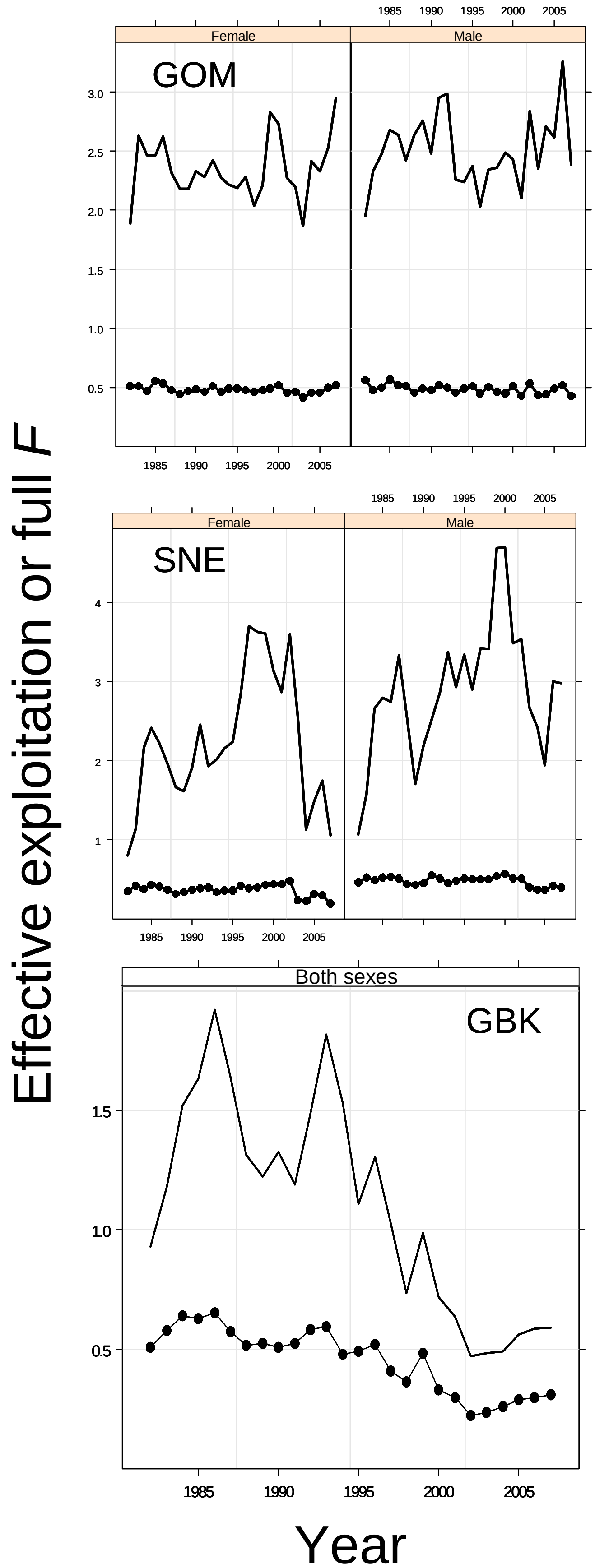


Figure 6.2.2. Effective exploitation vs. full *F* from basecase models.
The range of the x-axis differs among graphs.

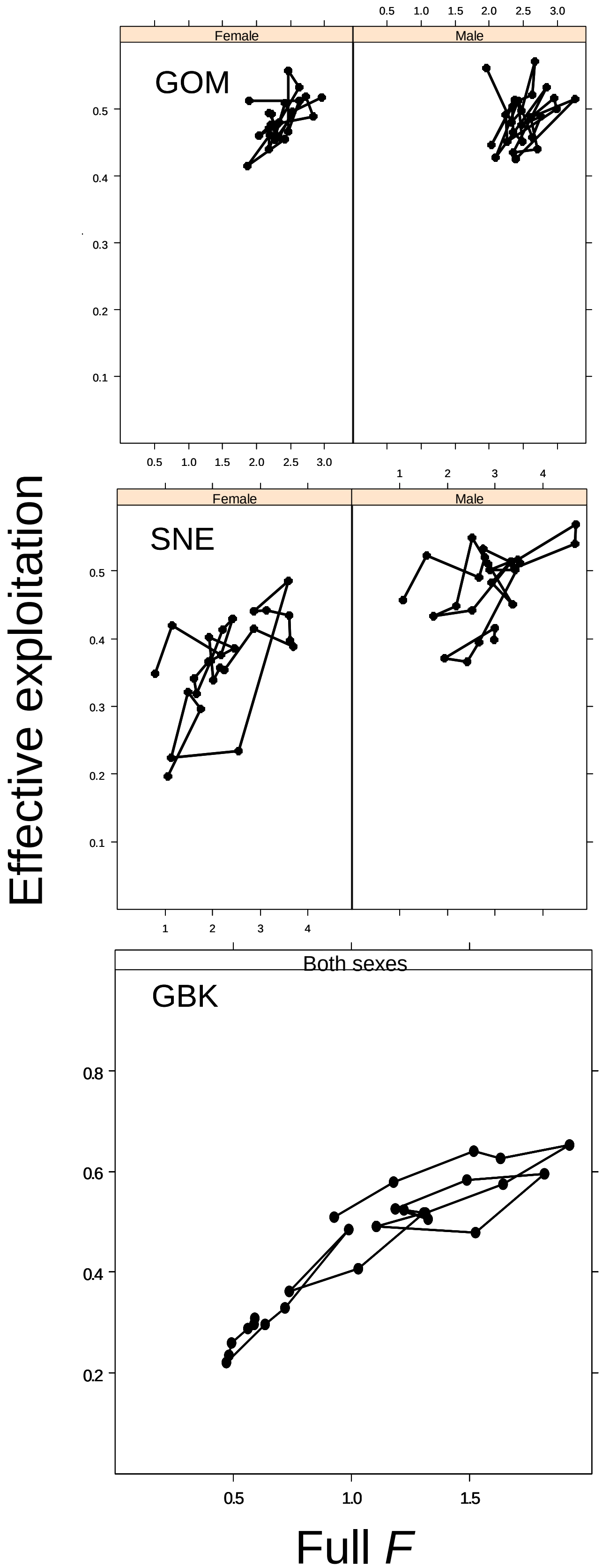


Figure 6.3.1. Trends in relative abundance of female and male lobster based on NEFSC spring and fall survey data from GBK.

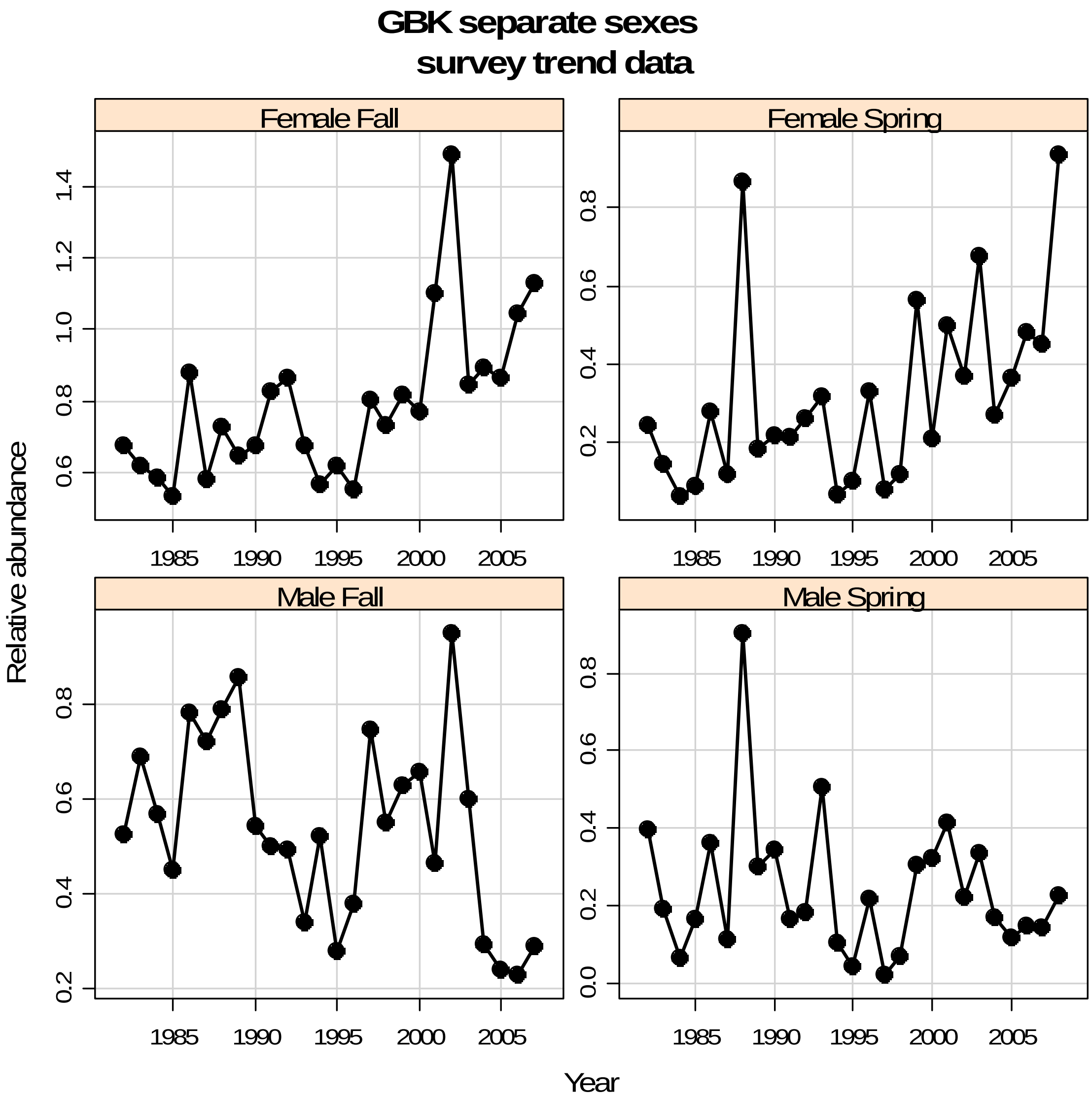


Figure 6.3.2. Trends in sex ratio (female number per tow / total number per tow) for lobster based on NEFSC spring and fall bottom trawl survey data from GBK.

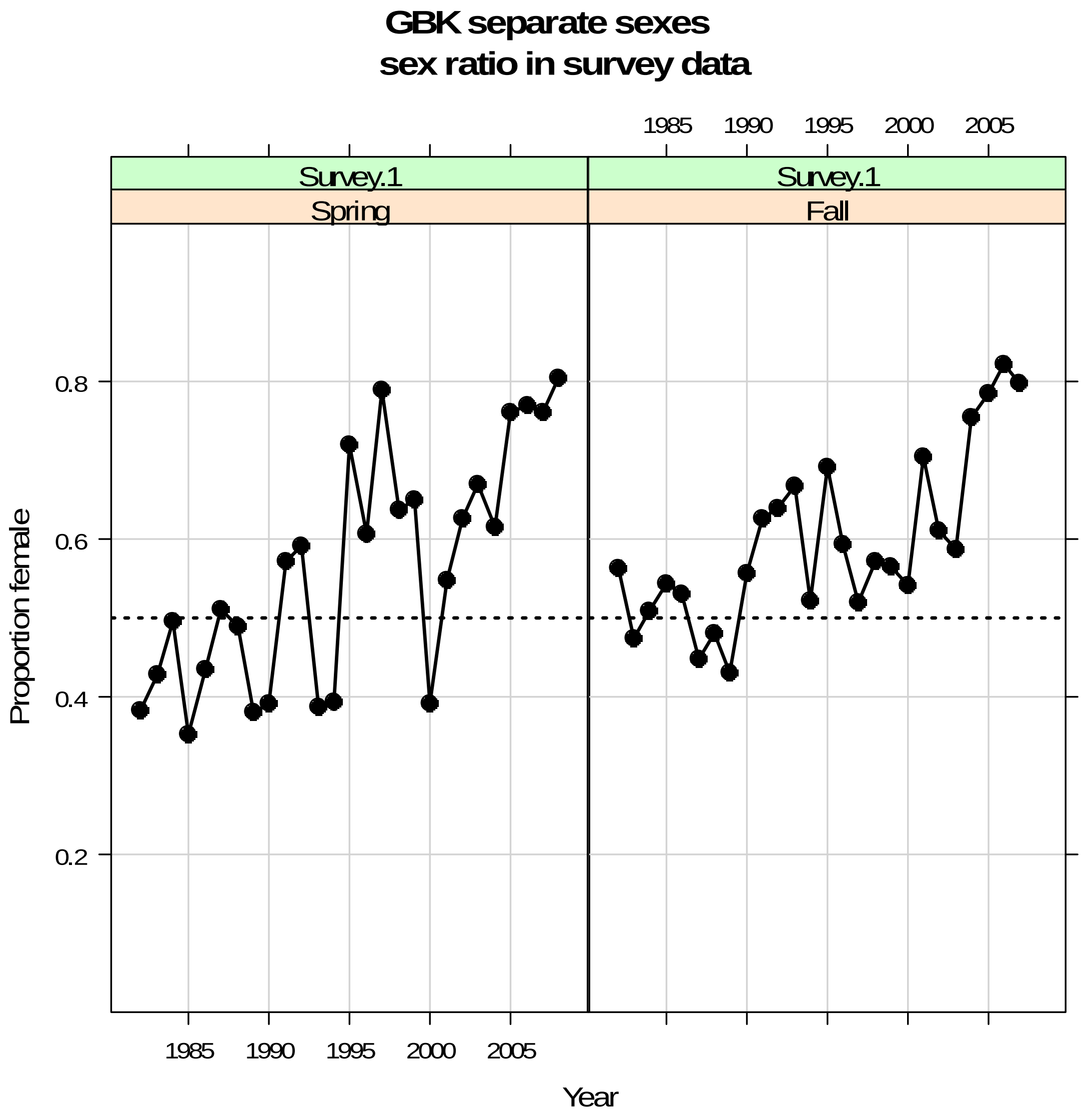


Figure 6.3.3. Landings data (mt) for female and male lobster from the GBK stock area.

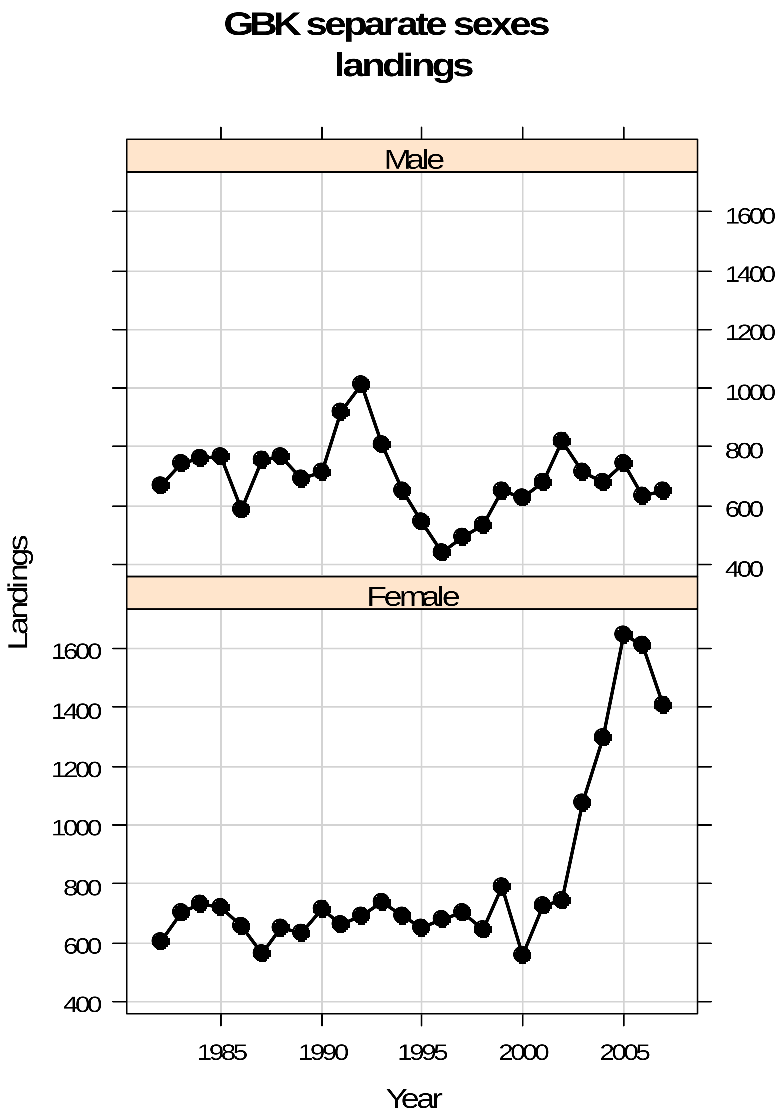


Figure 6.3.4. Trends in sex ratio (female number per tow / total number per tow) for GBK lobster landings.

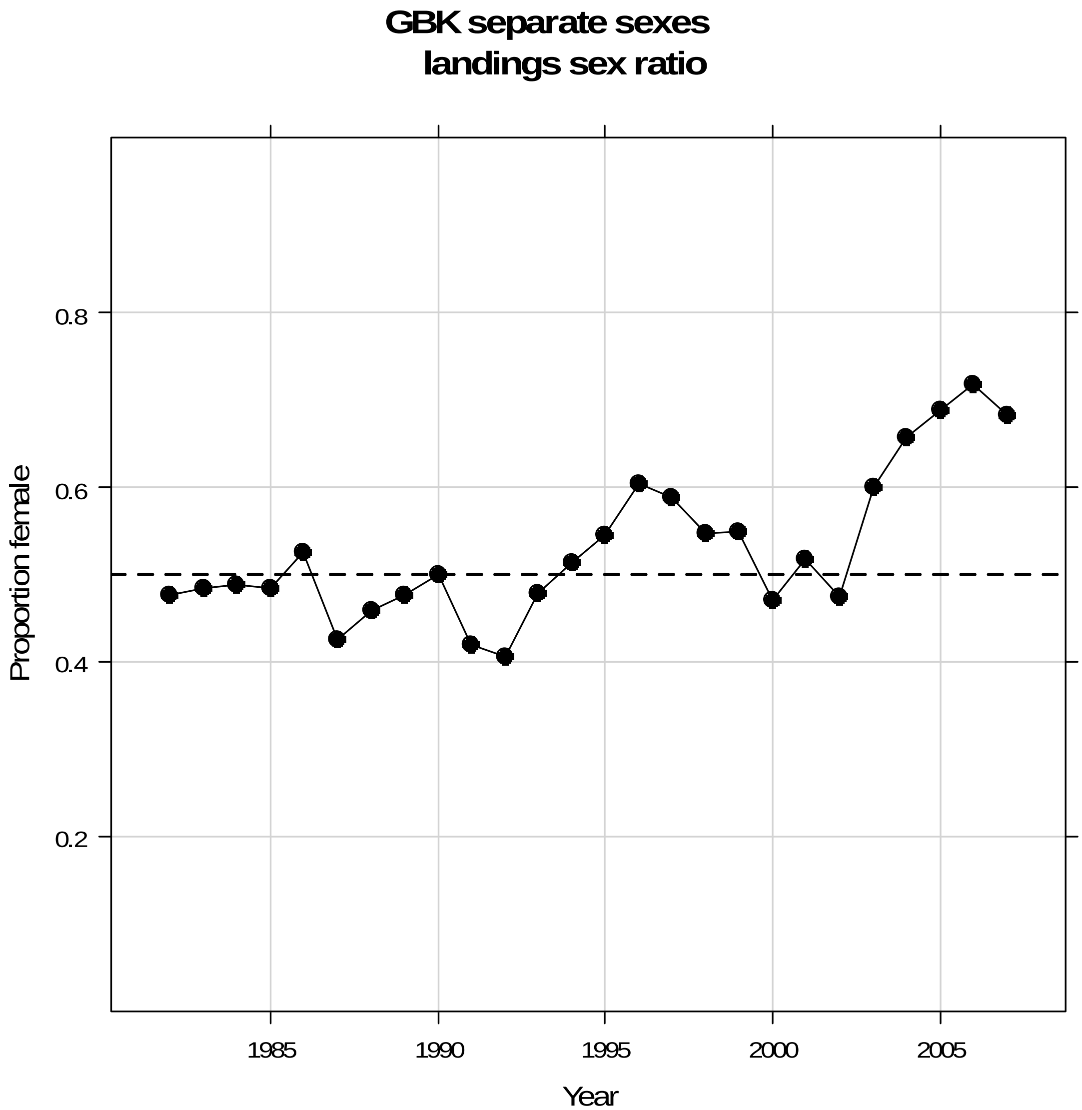


Figure 6.3.5. Proportions of female and male lobster with eggs or v-notches on Georges Bank, based on sea sample data

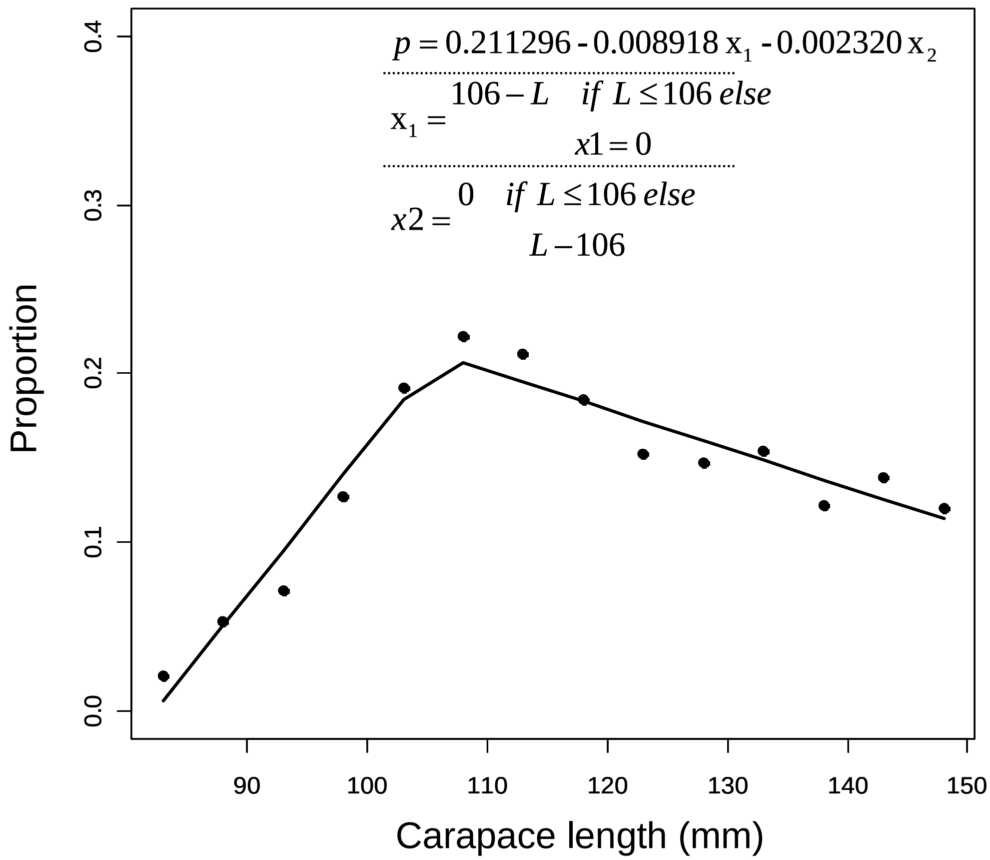


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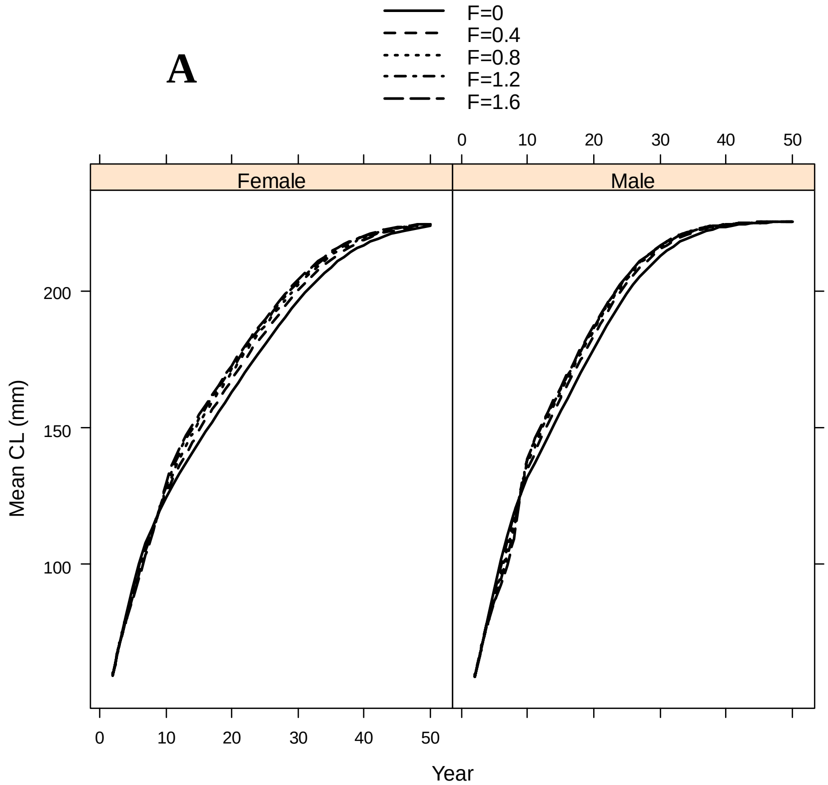
Figure 6.3.6. Apparent growth of a cohort with fishing in A) GOM, B) GBK, and C) SNE assessment models.



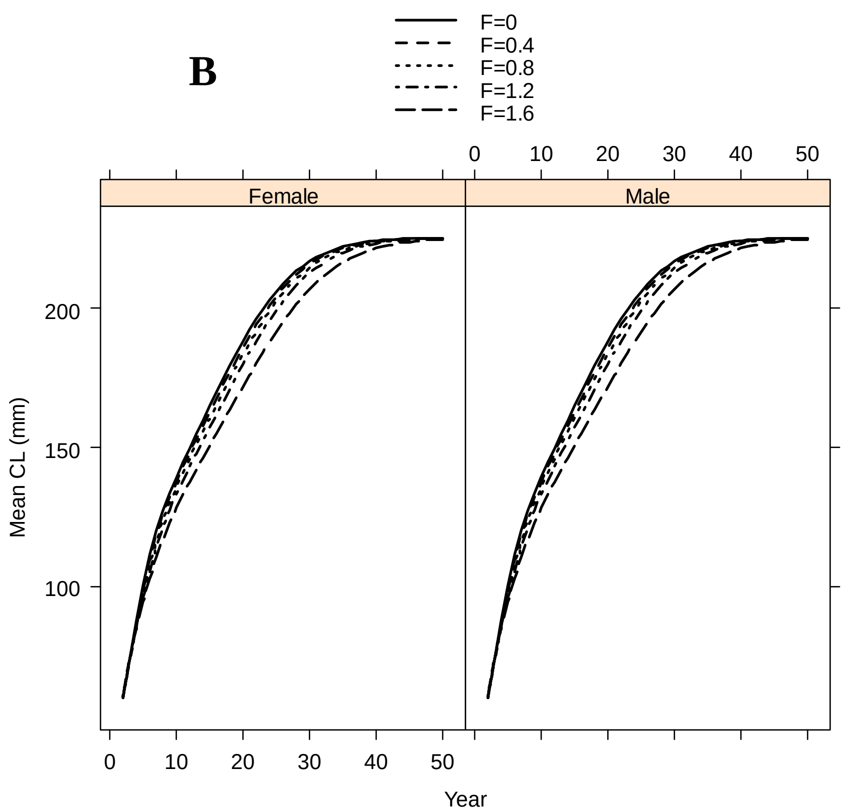


Figure 6.3.6. Continued: Apparent growth of a cohort with fishing in A) GOM, B) GBK, and C) SNE assessment models.

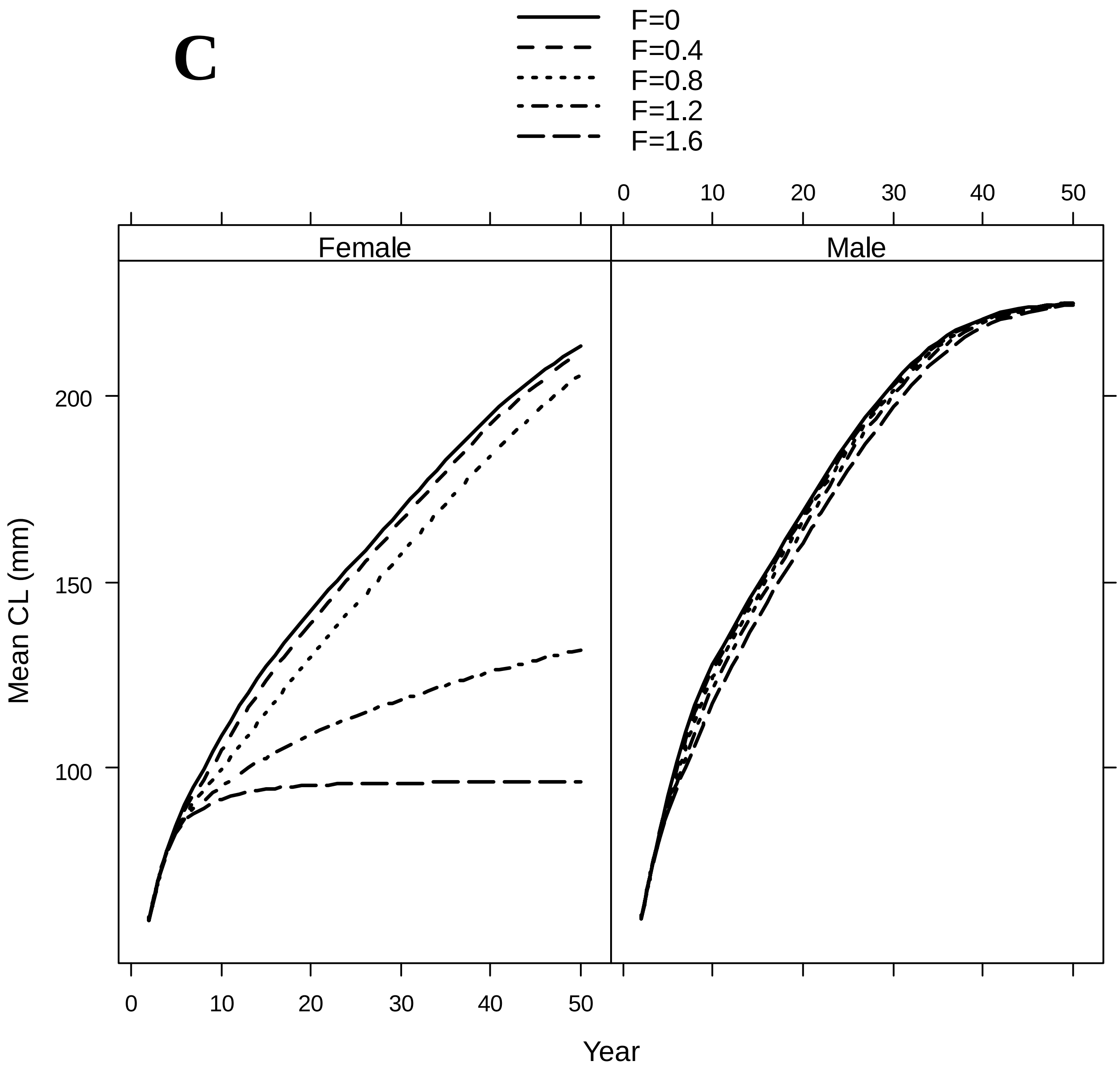


Figure 7.1.1.1. CSM population dynamics for male and female lobster in GOM.

Figure 7.1.1.2. CSM estimates and residuals for GOM recruit and post-recruit MA DMF survey data by sex.

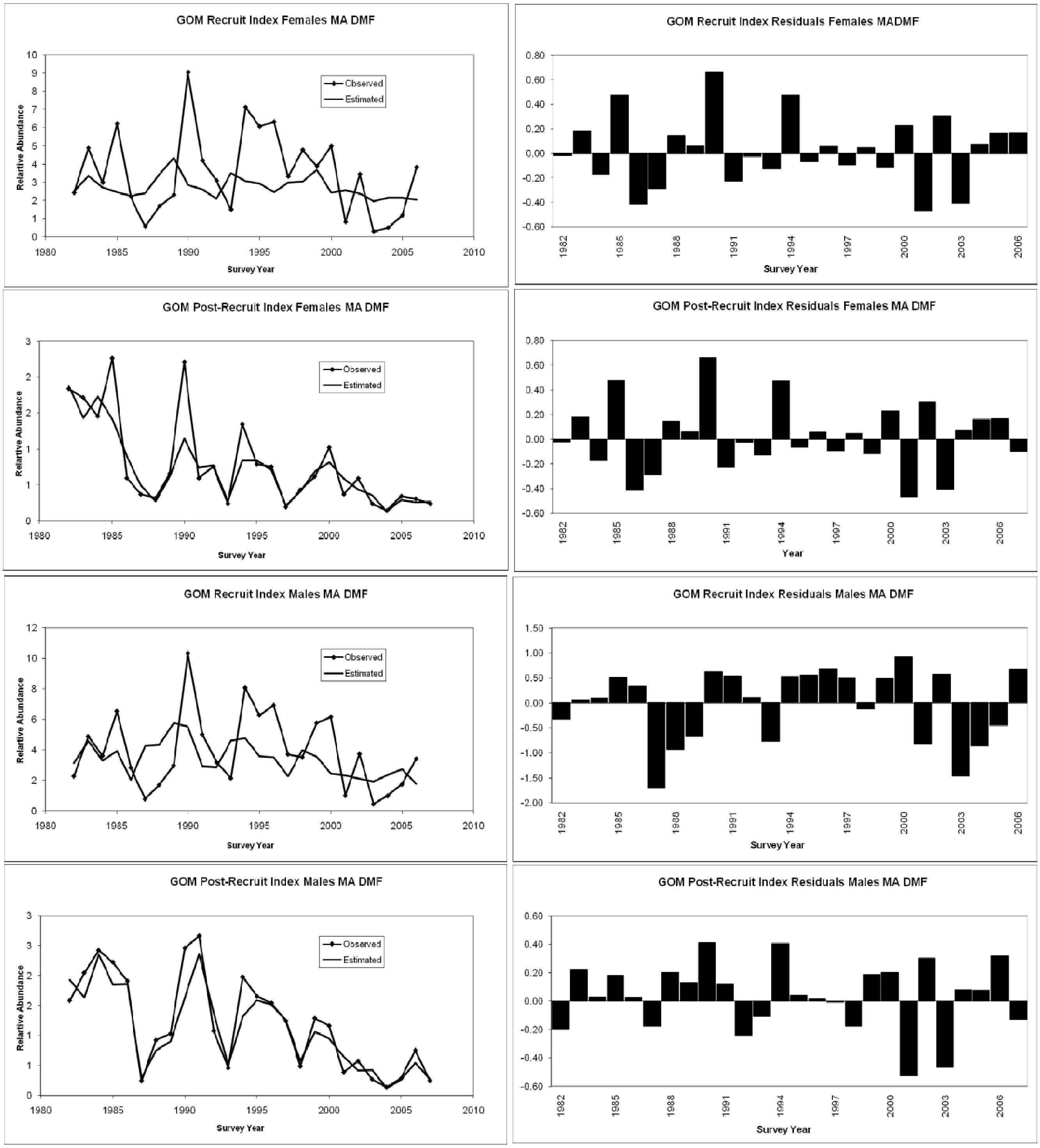


Figure 7.1.1.3. CSM estimates and residuals for GOM recruit and post-recruit NEFSC survey data by sex.

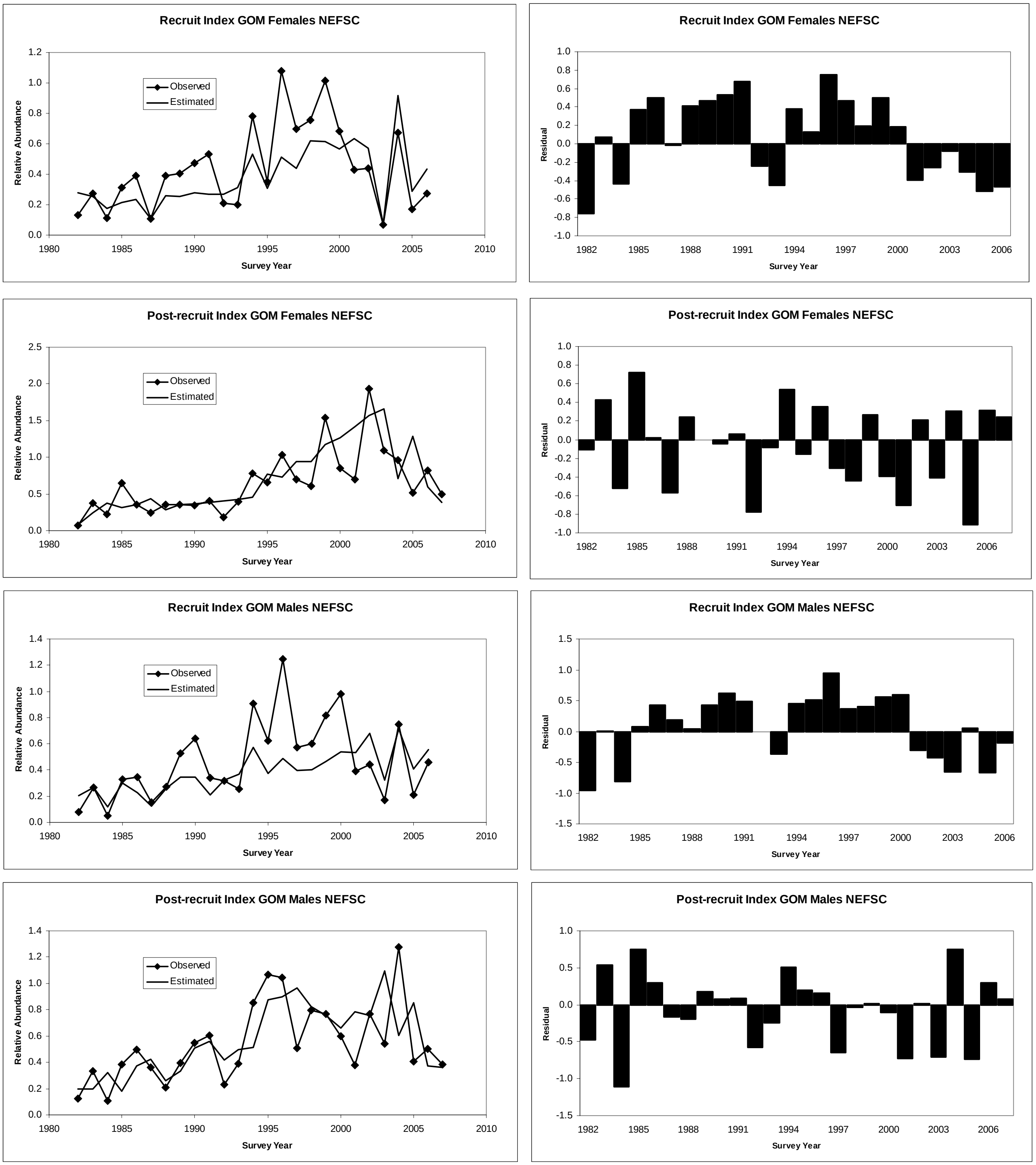


Figure 7.1.2.1 CSM population dynamics for male and female lobster in GBK.

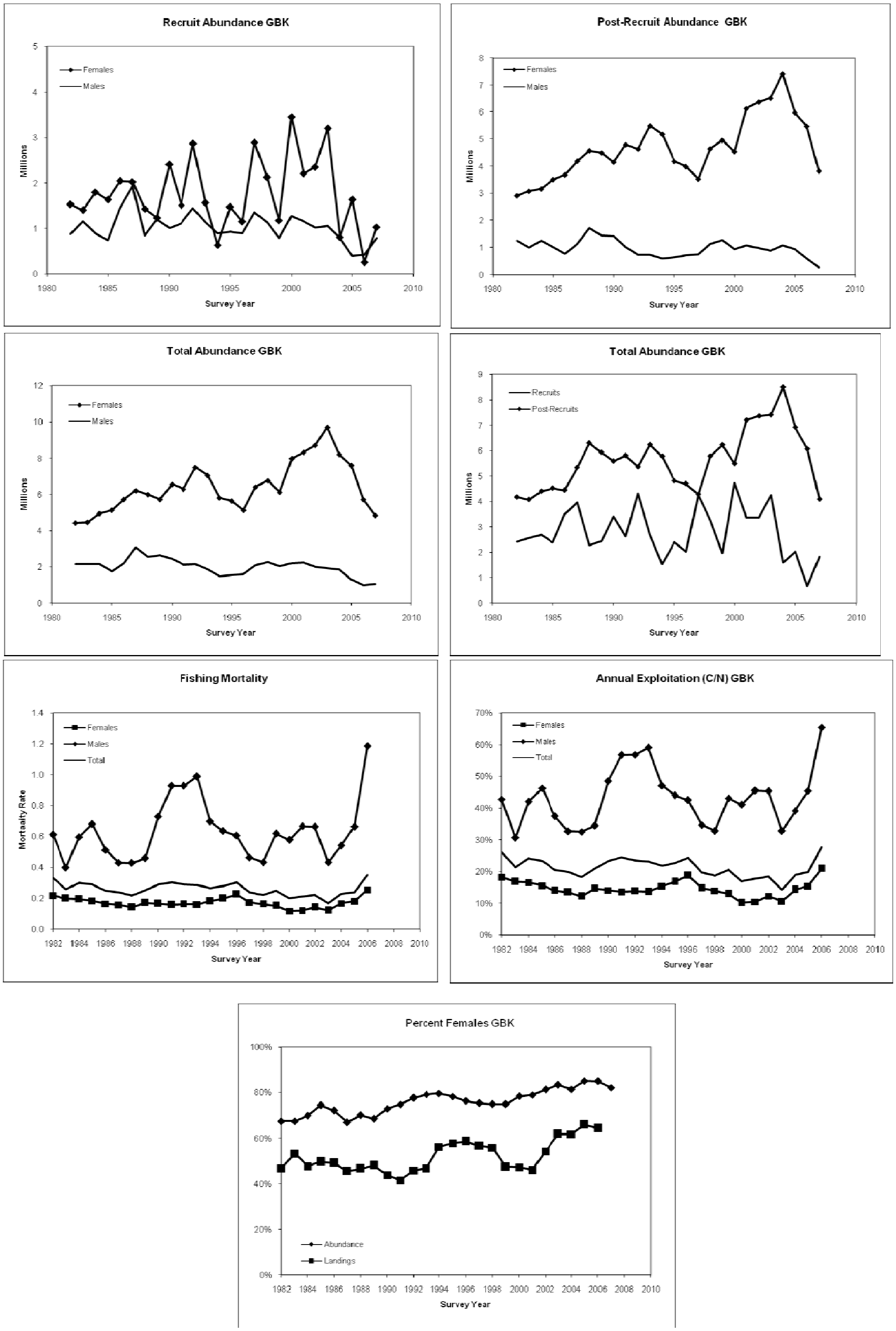


Figure 7.1.2.2. CSM estimates and residuals for GBK recruit and post-recruit NEFSC survey data by sex.

Figure 7.1.3.1. CSM population dynamics for male and female lobster in SNE.

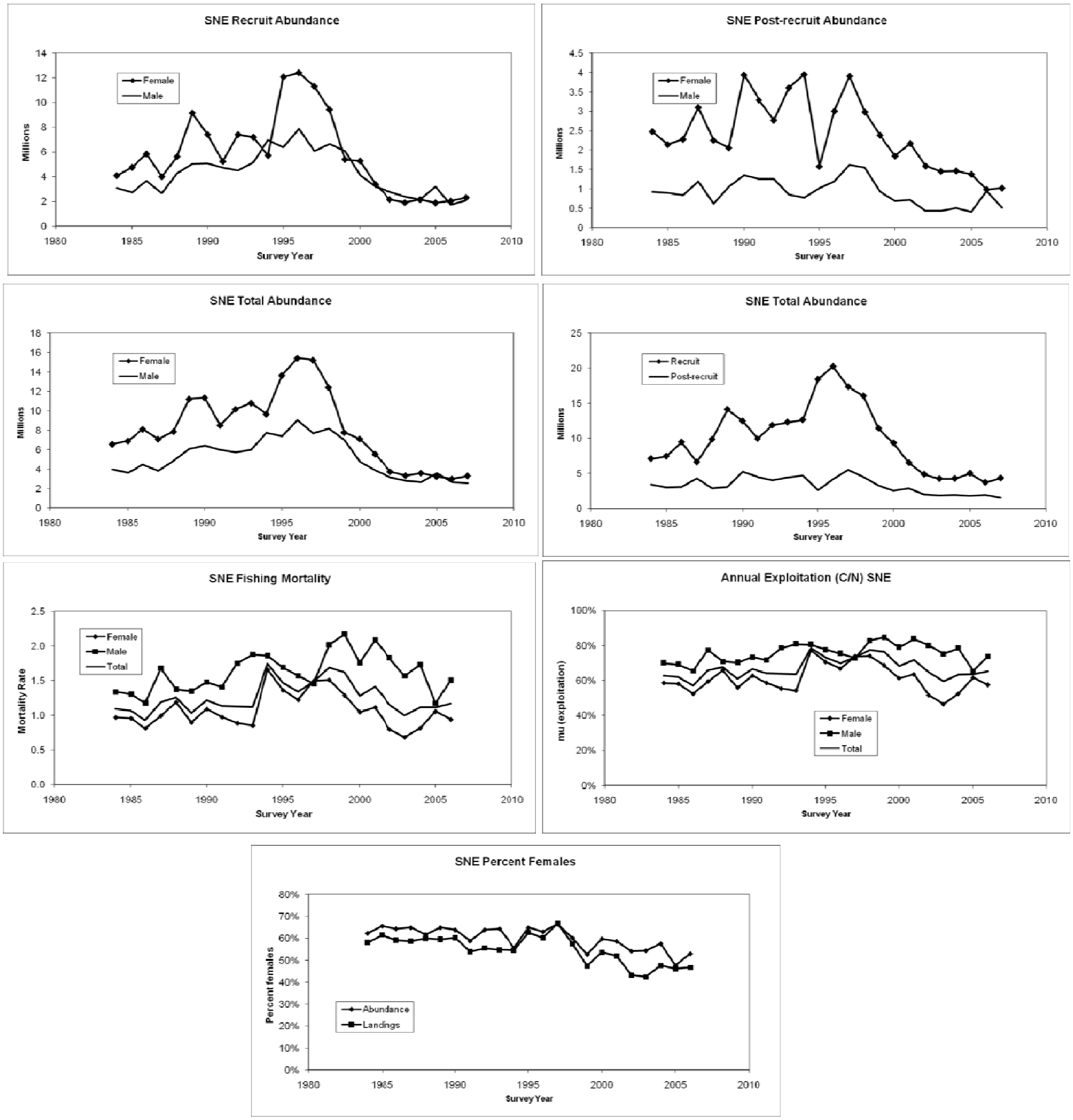


Figure 7.1.3.2. CSM estimates and residuals for SNE recruit and post-recruit CT DEP survey data by sex.

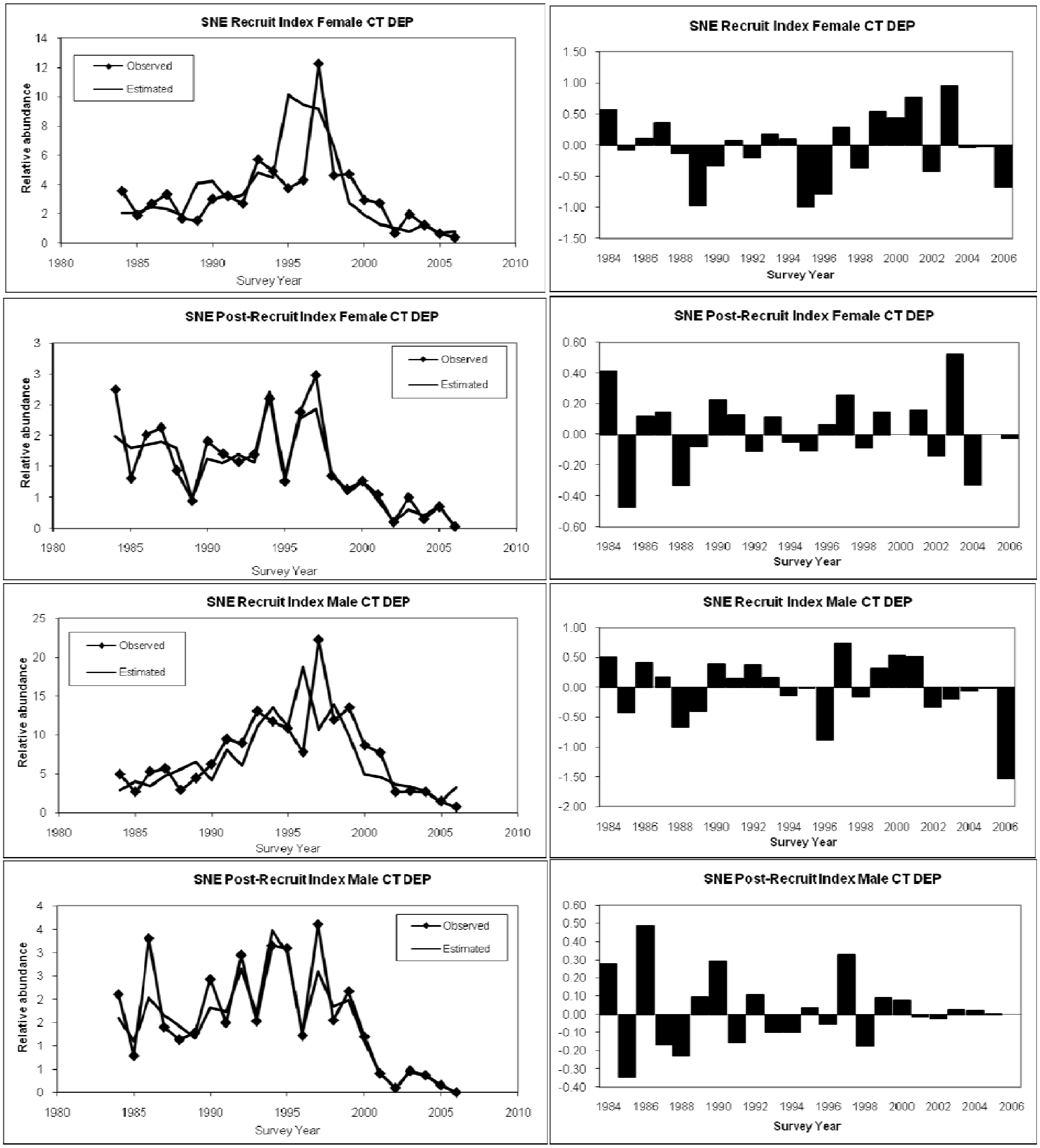


Figure 7.1.3.3. CSM estimates and residuals for SNE recruit and post-recruit RI DEM survey data by sex.

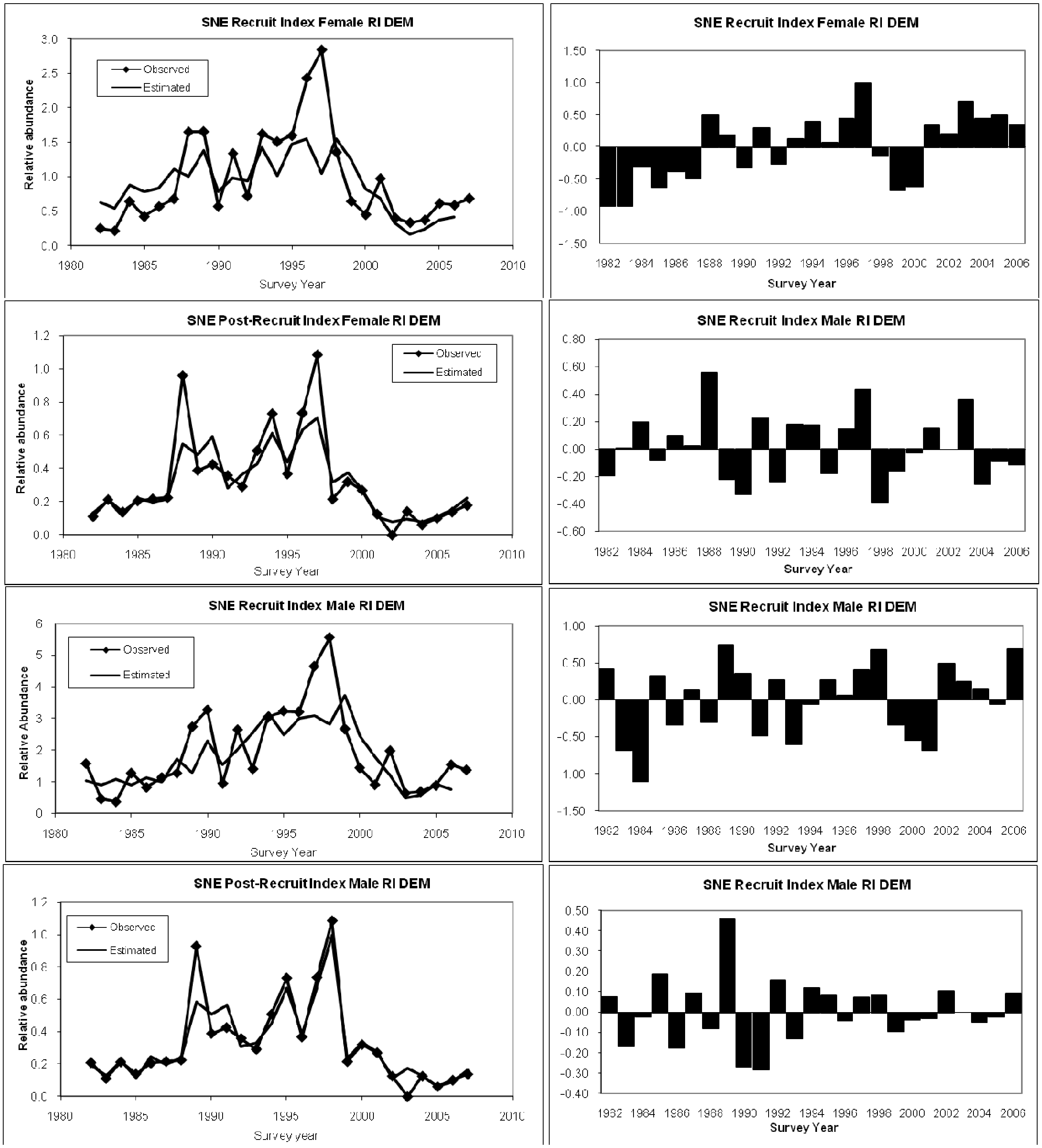


Figure 7.1.3.4. CSM estimates and residuals for SNE recruit and post-recruit NEFSC survey data by sex.

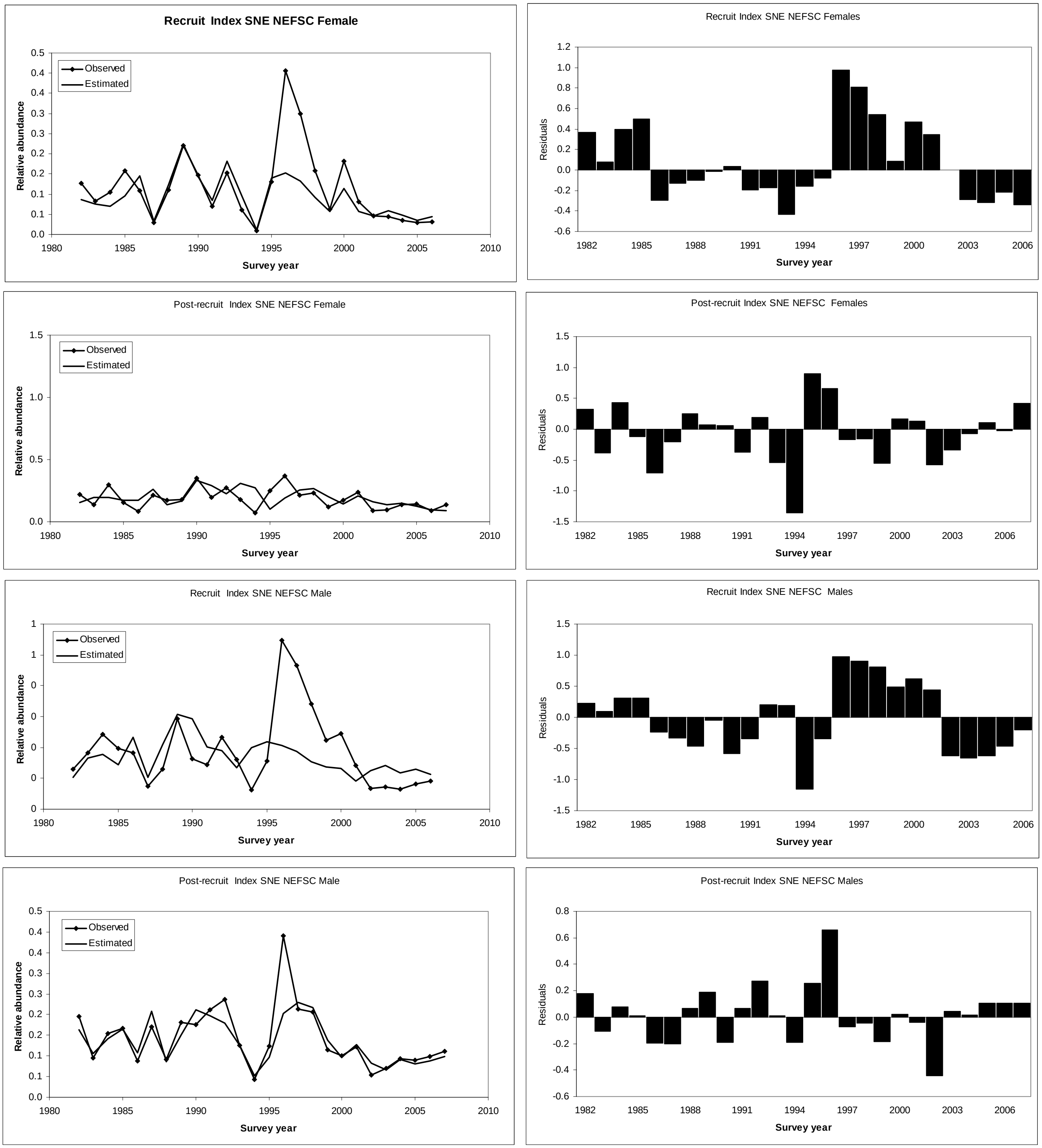


Figure 7.2.1.1. Diagnostics for NEFSC fall trawl survey trend data used in the GOM basecase model.

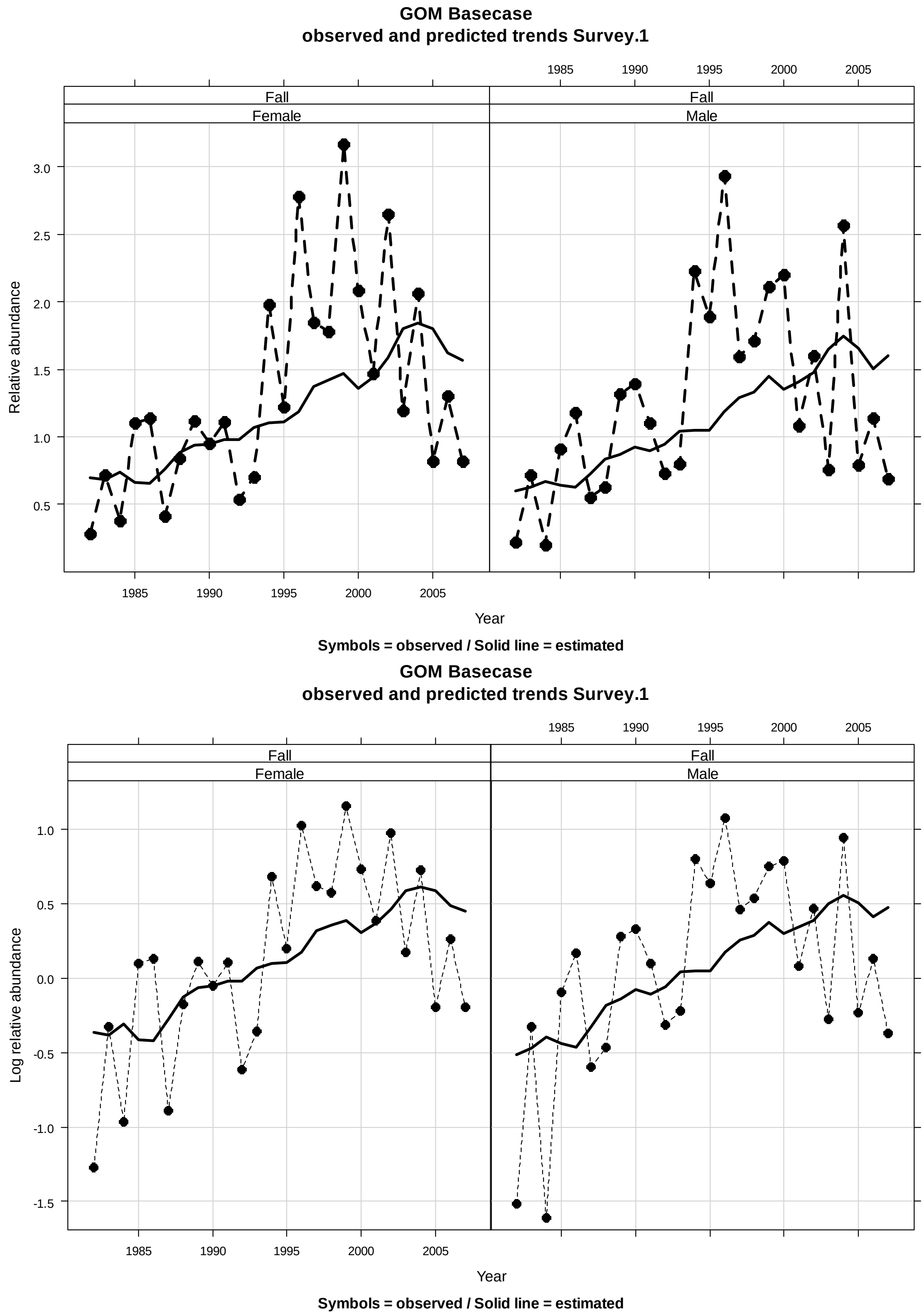


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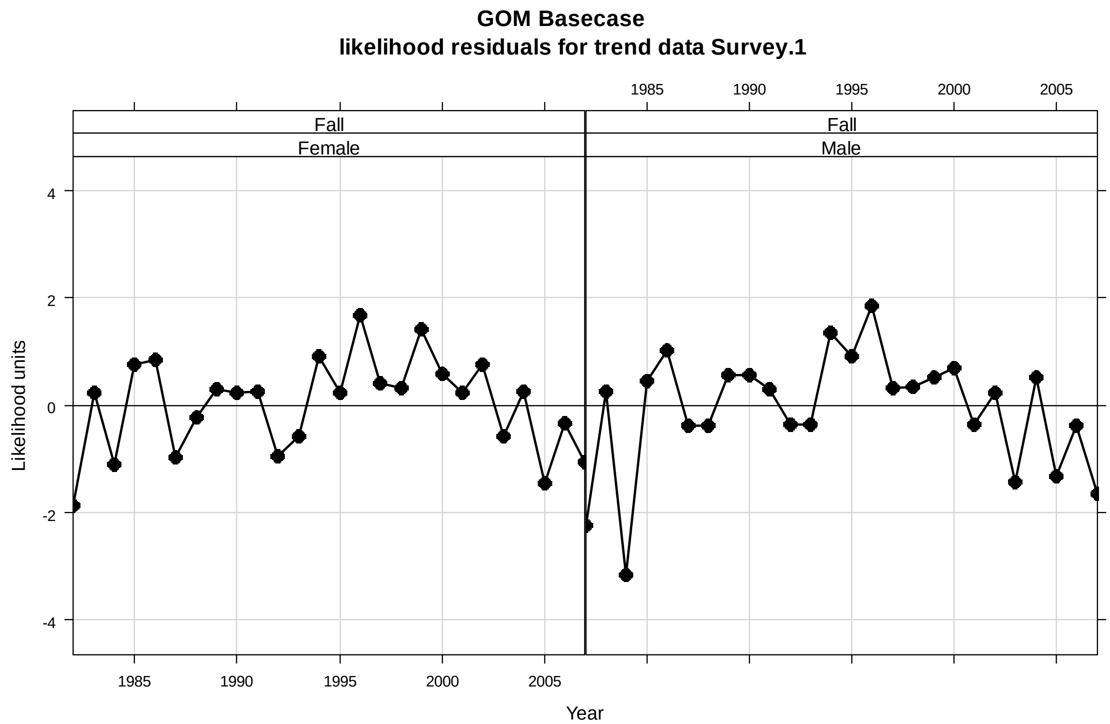
Figure 7.2.1.1. Continued. Diagnostics for NEFSC fall trawl survey trend data used in the GOM basecase model.



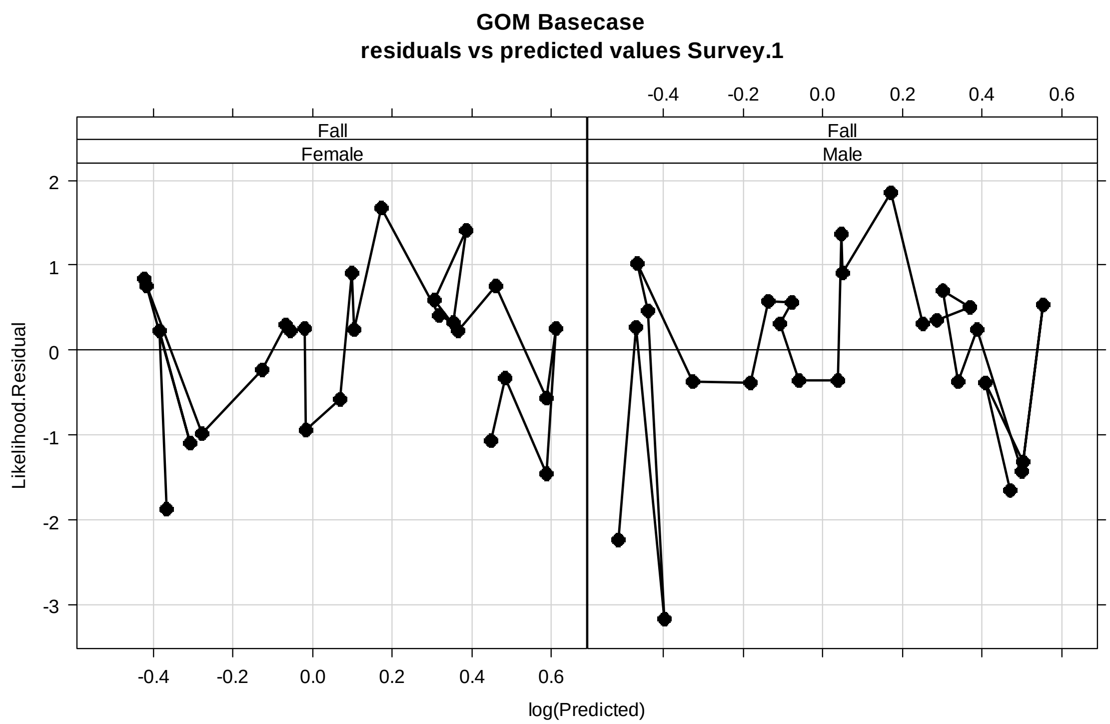
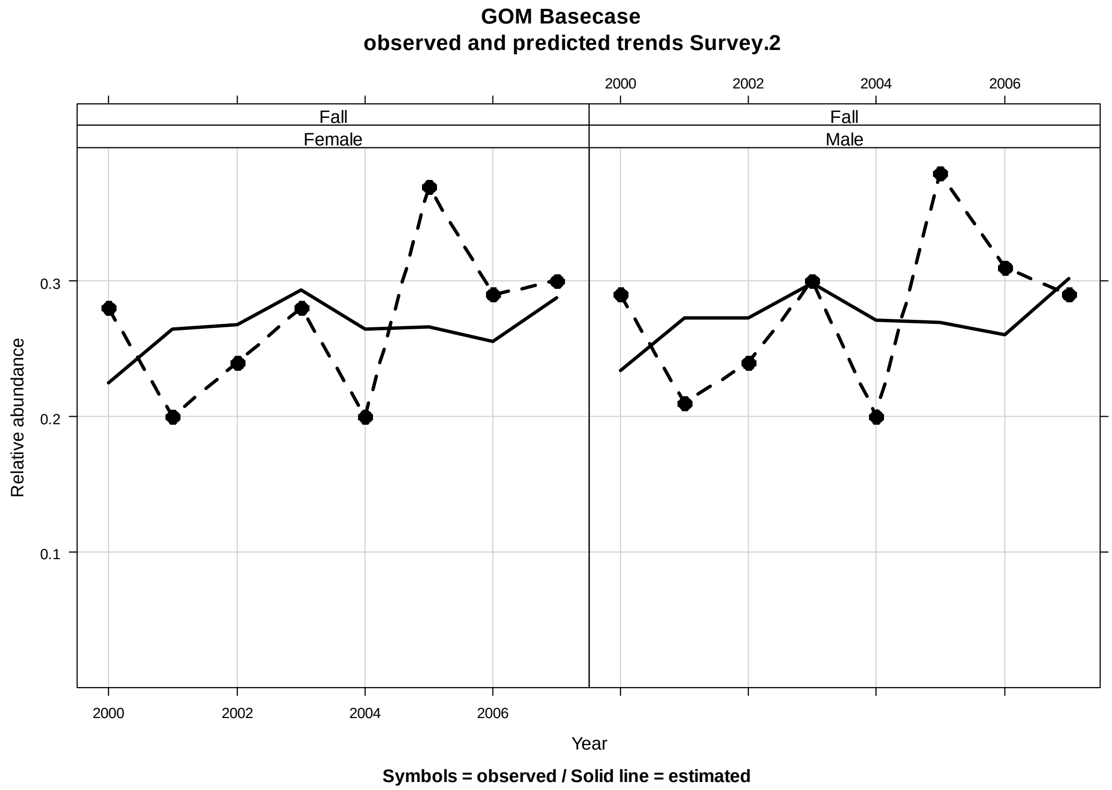


Figure 7.2.1.2. Diagnostics for ME DMR fall trawl survey trend data used in the GOM basecase model.



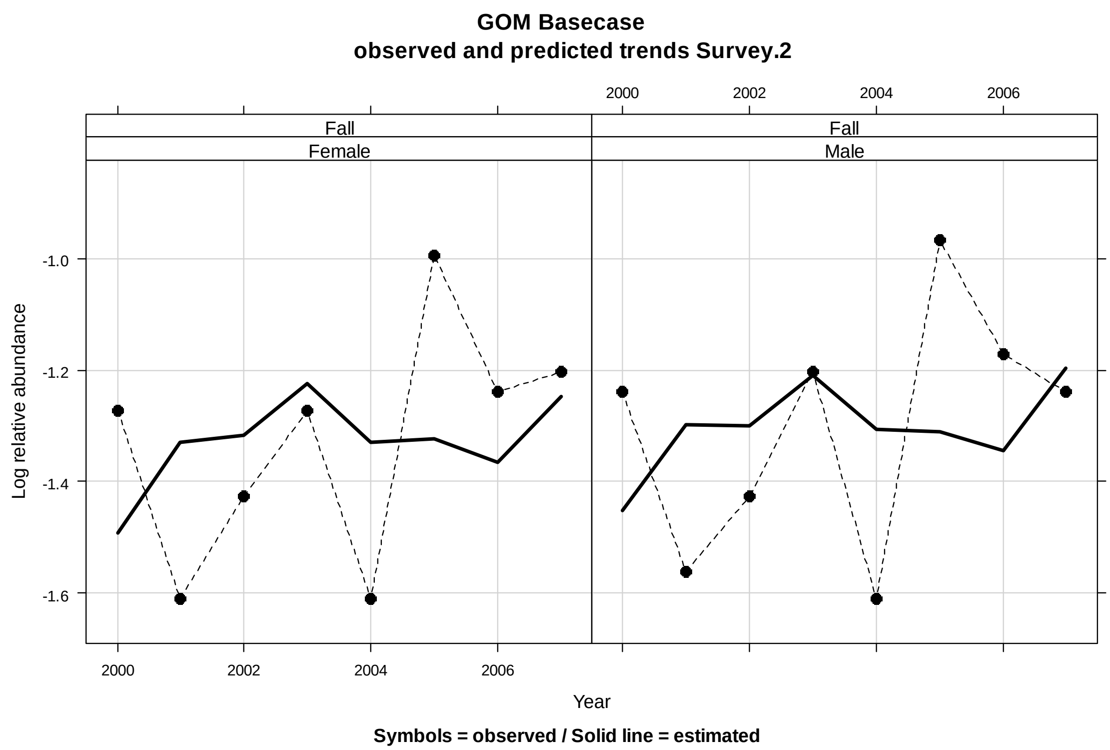
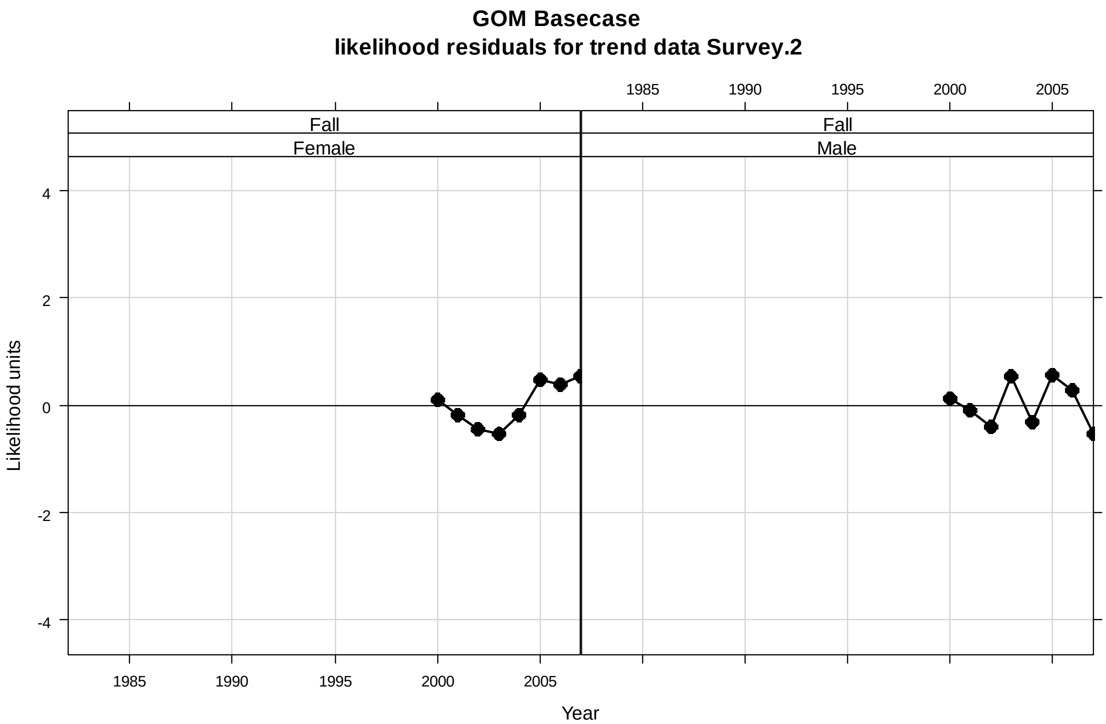


Figure 7.2.1.2. Continued. Diagnostics for ME DMR fall trawl survey trend data used in the GOM basecase model.



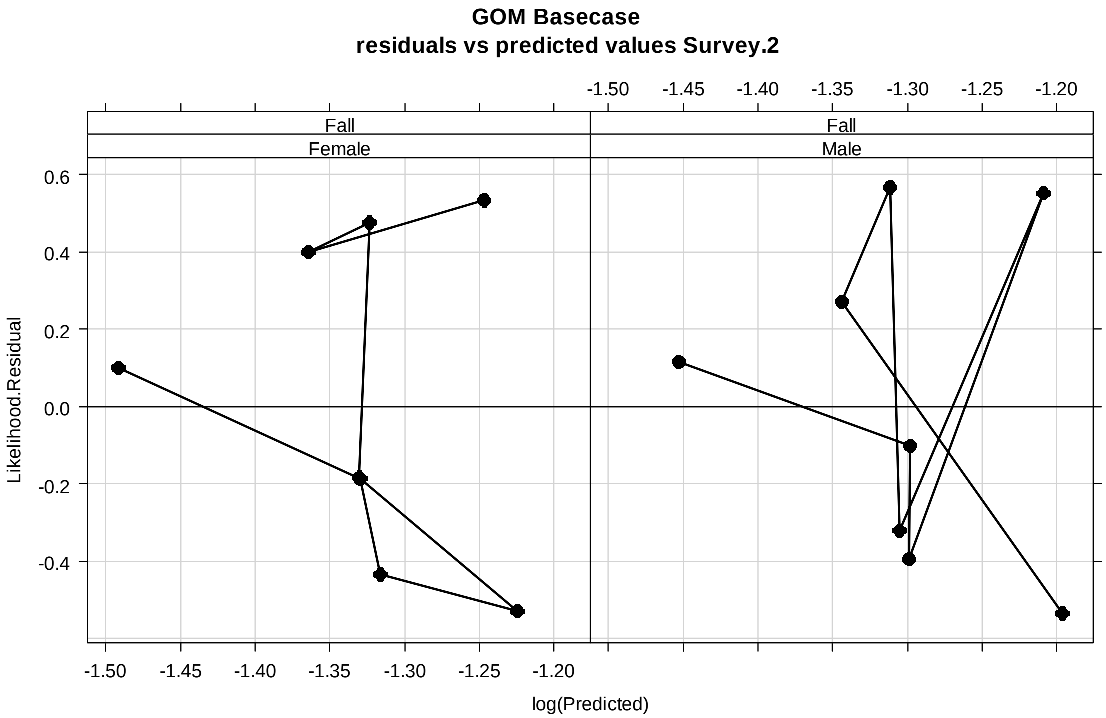
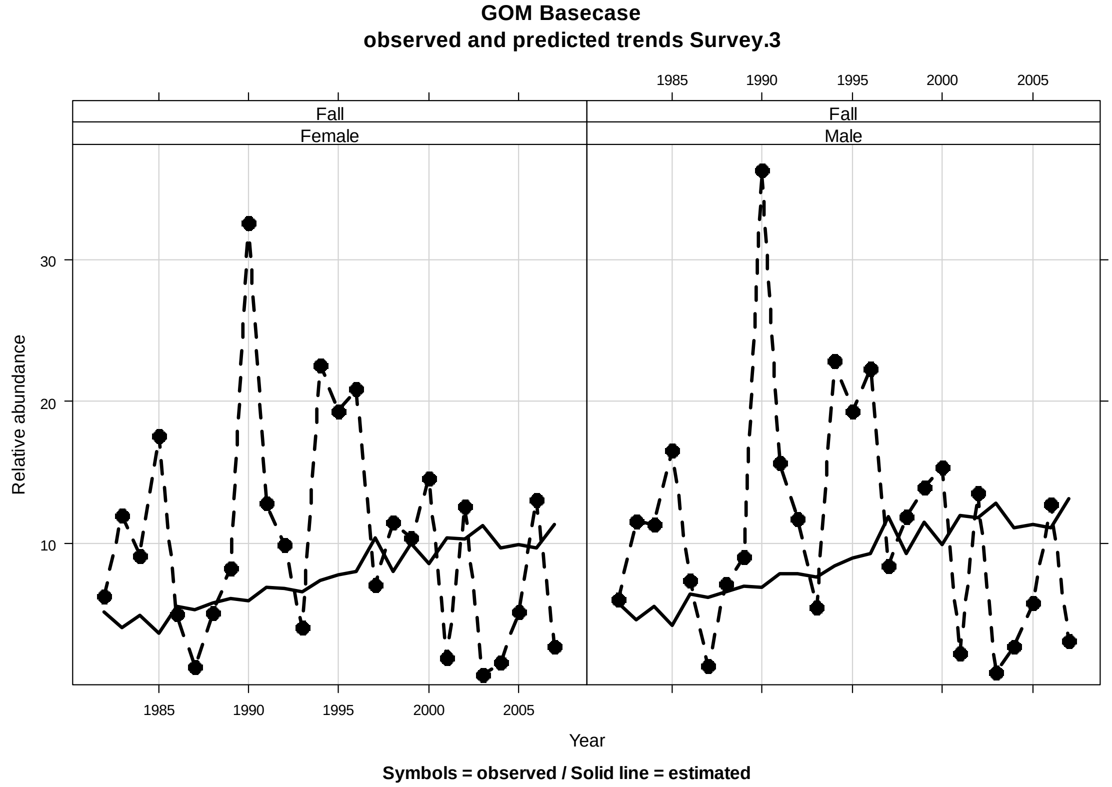


Figure 7.2.1.3. Diagnostics for MA DMF fall trawl survey trend data used in the GOM basecase model.



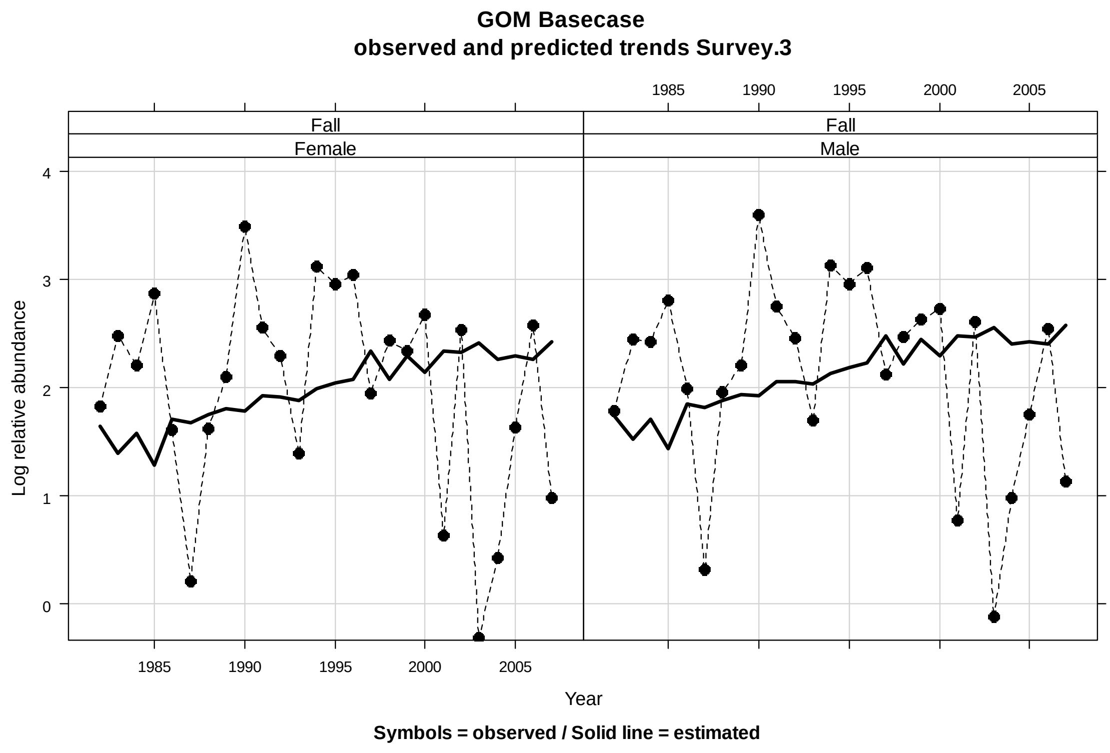
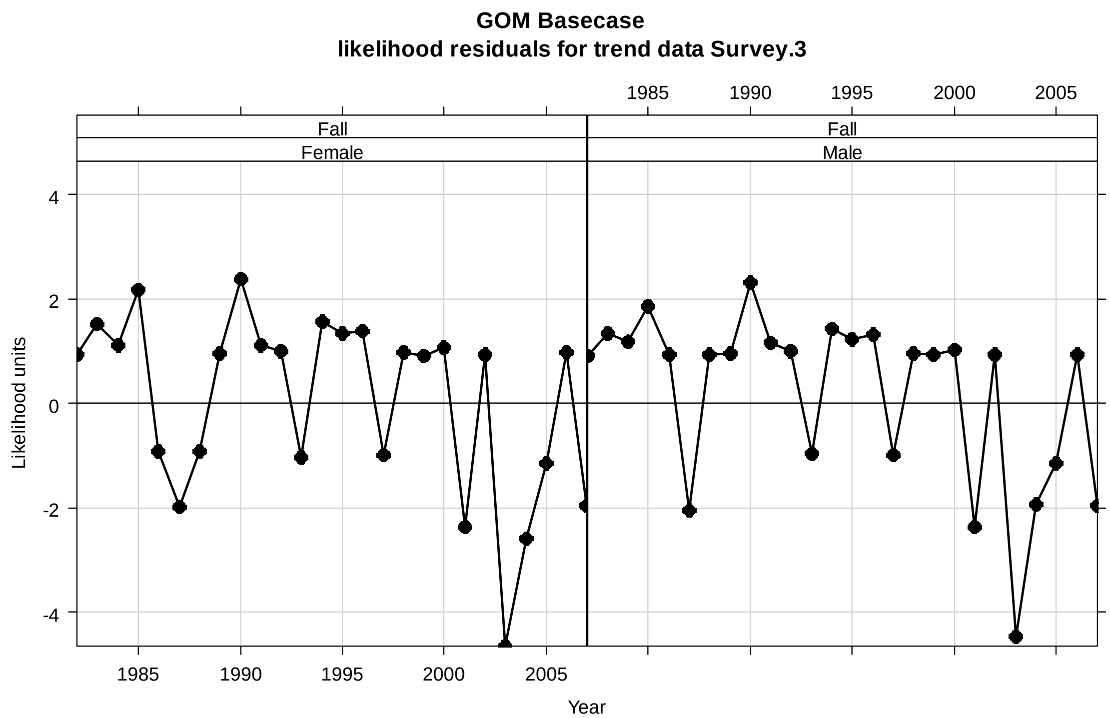


Figure 7.2.1.3. Continued. Diagnostics for MA DMF fall trawl survey trend data used in the GOM basecase model.



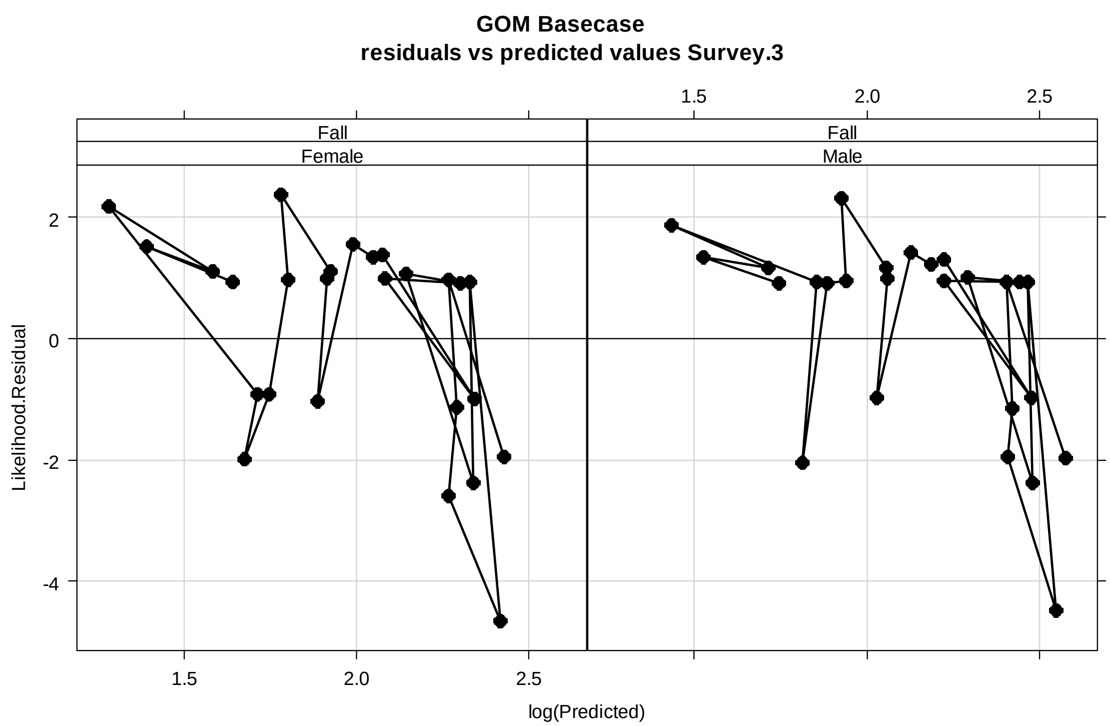


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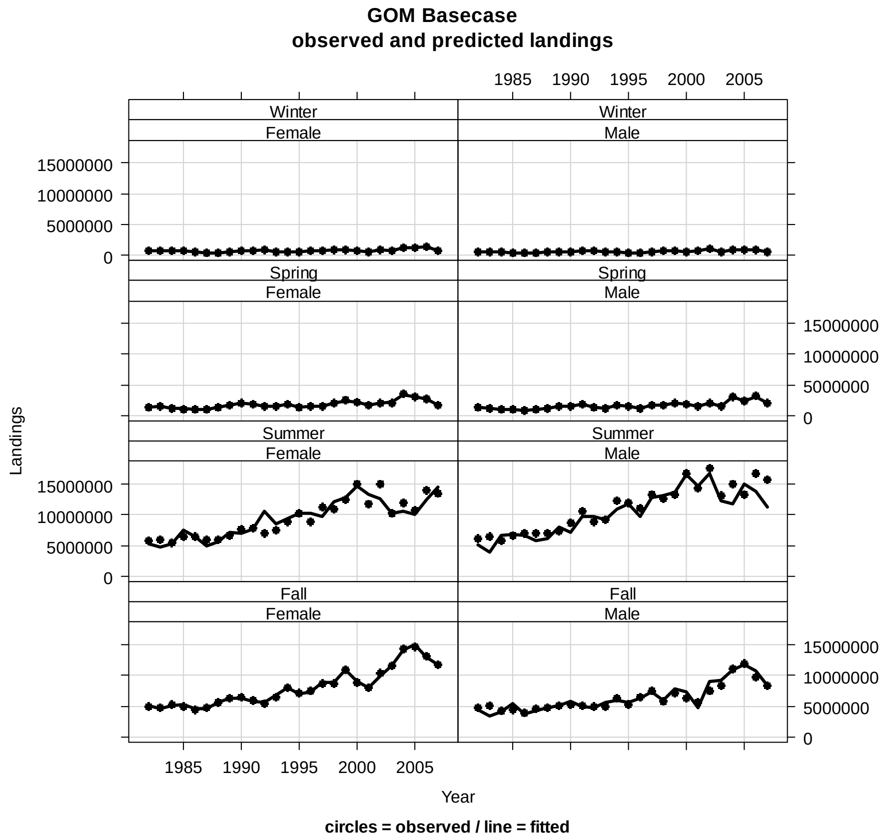
Figure 7.2.1.4. Observed and predicted landings by season (above) and annually (below) for lobster from the GOM basecase model.



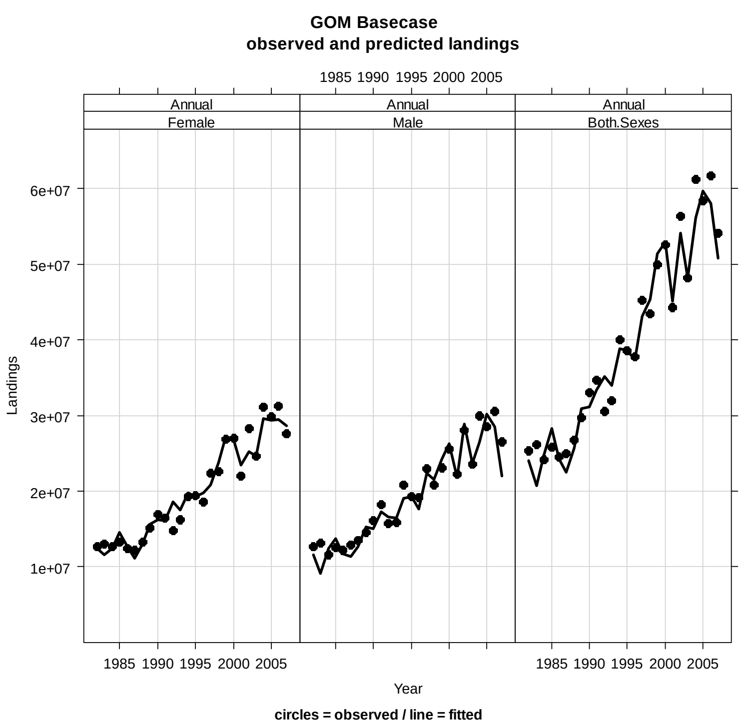


Figure 7.2.1.5. Example graphs of observed and predicted female catch at length data from the basecase model for GOM: A) Commercial B) NEFSC fall survey C) ME DMF fall survey D) MA DMF fall survey.

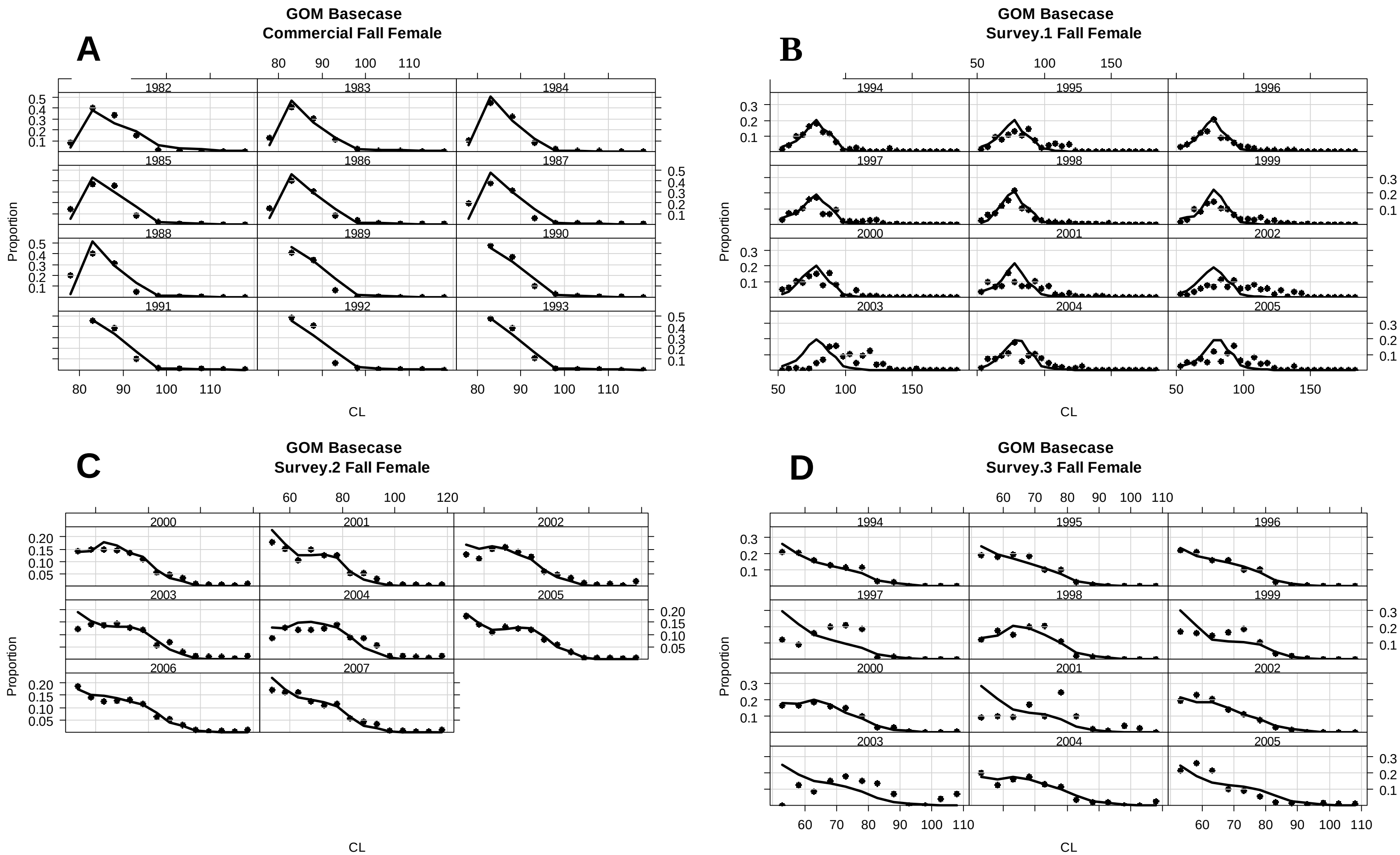


Figure 7.2.1.6. Example graphs of observed and predicted male catch at length data from the basecase model for GOM: A) Commercial B) NEFSC fall survey C) ME DMF fall survey D) MA DMF fall survey.

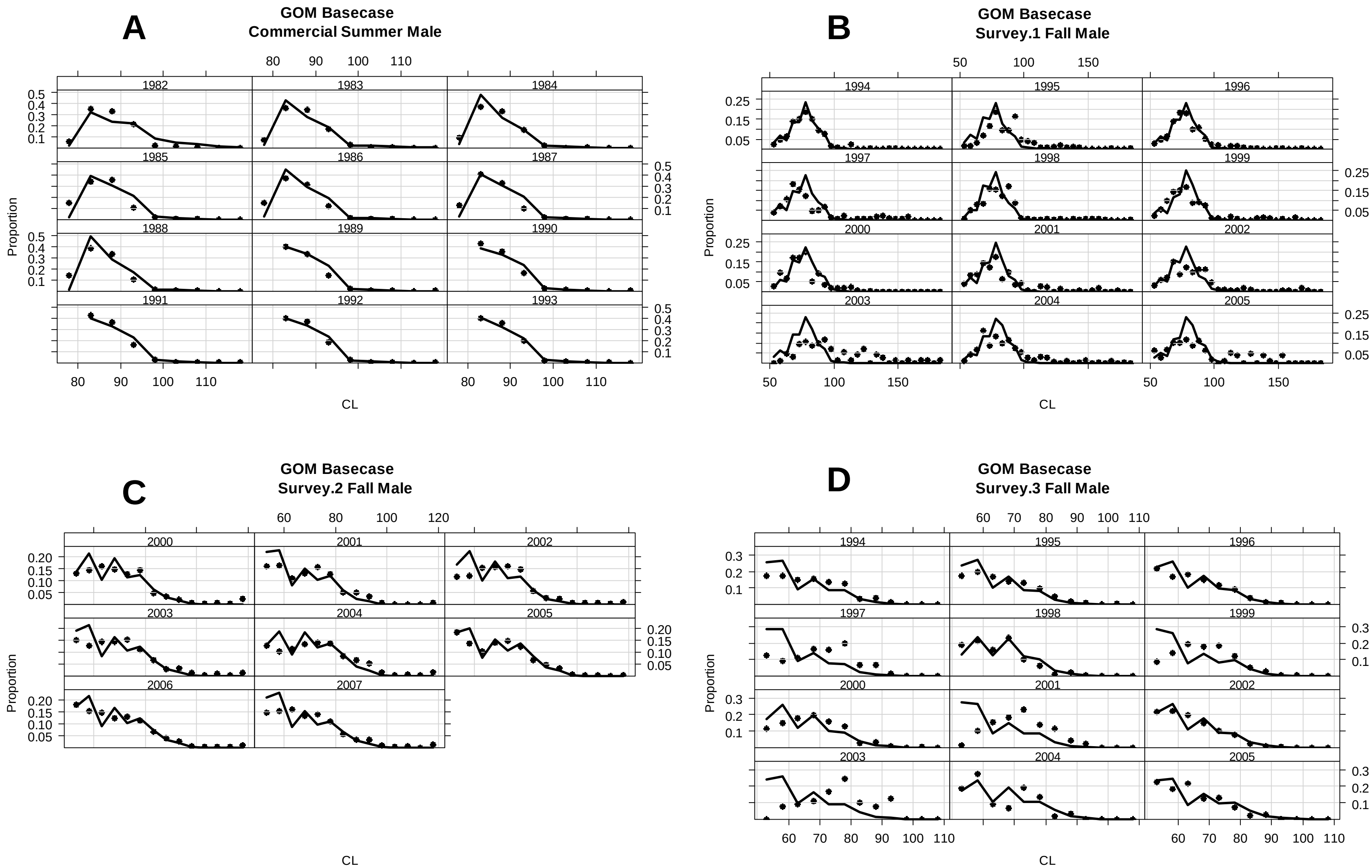
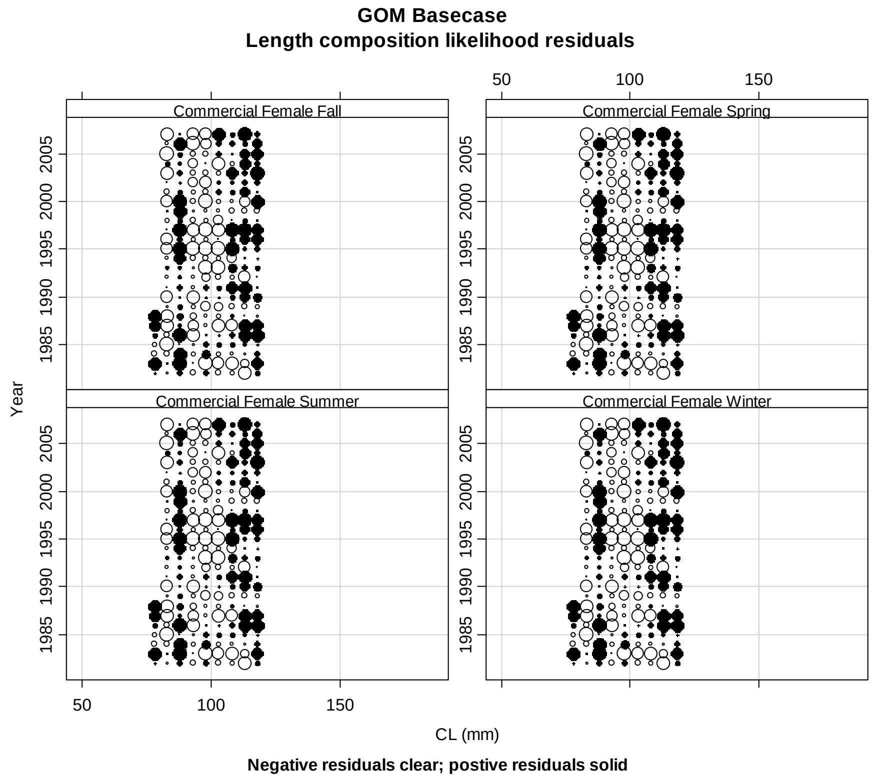


Figure 7.2.1.7. Likelihood residuals for female (above) and male (below) commercial length data in the GOM basecase model.



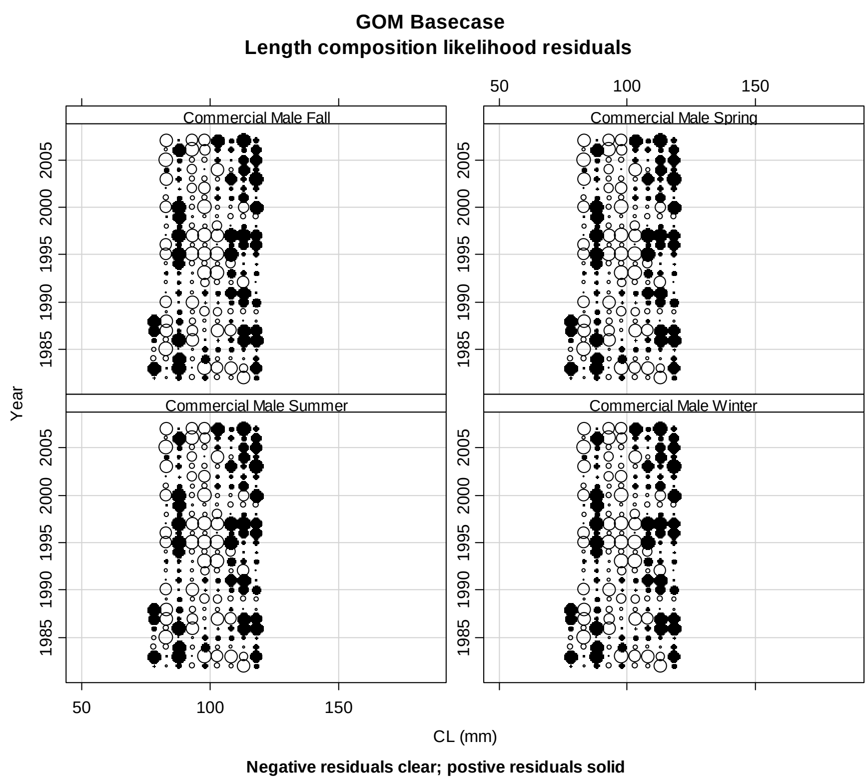
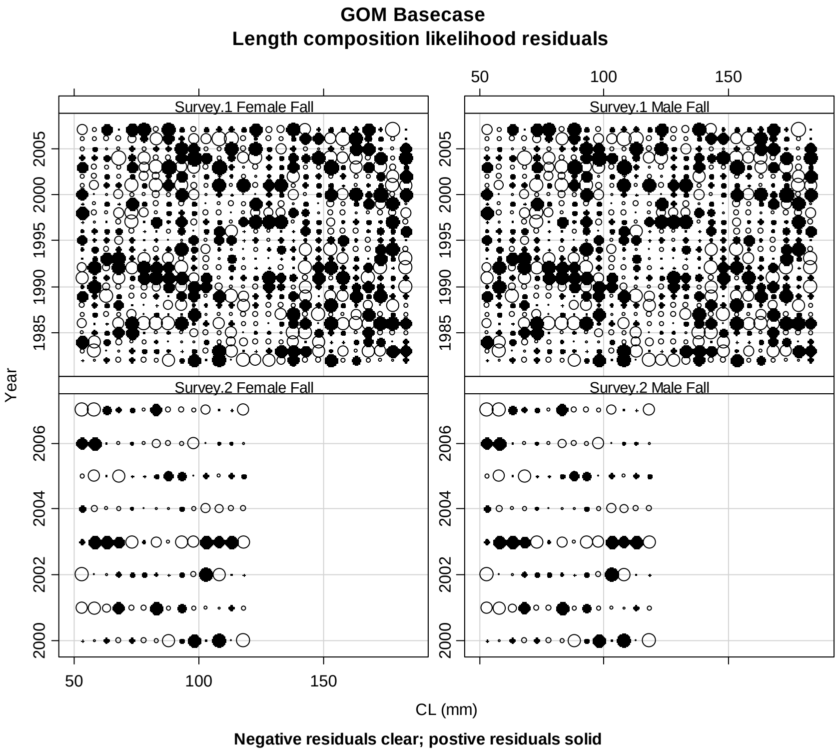


Figure 7.2.1.8. Likelihood residuals for survey length data in the GOM basecase model. Survey 1 = NEFSC fall survey, Survey 2 = ME DMR fall survey, and Survey 3 = MA DMF fall survey.



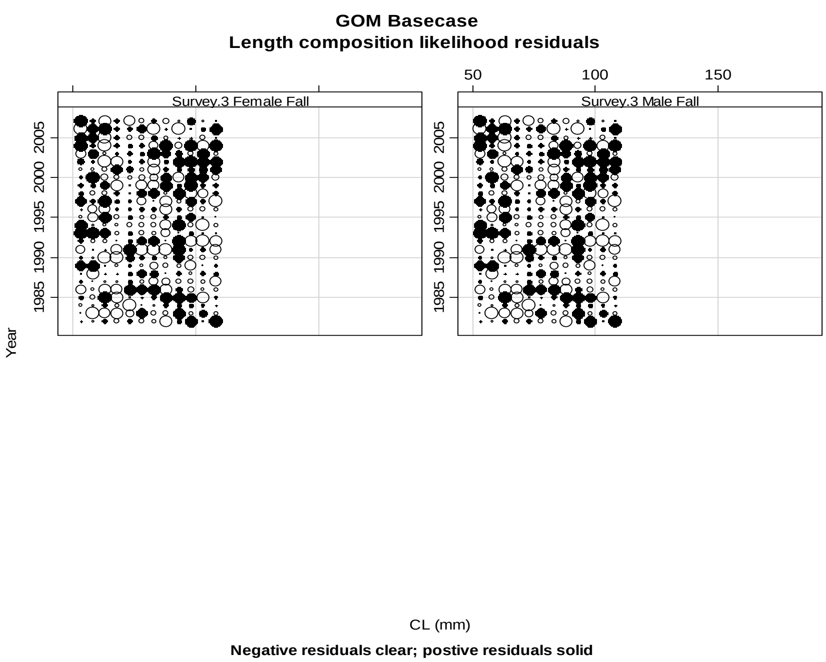
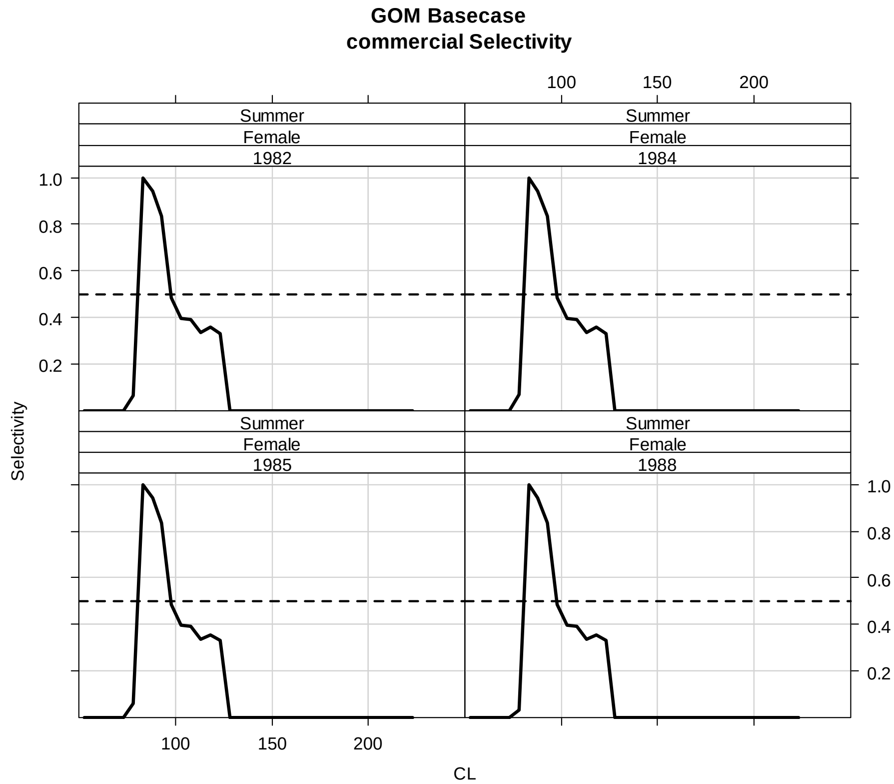


Figure 7.2.1.9. Example annual specified commercial selectivity curves for females (first 5) and males (last 3) in the basecase model for GOM.



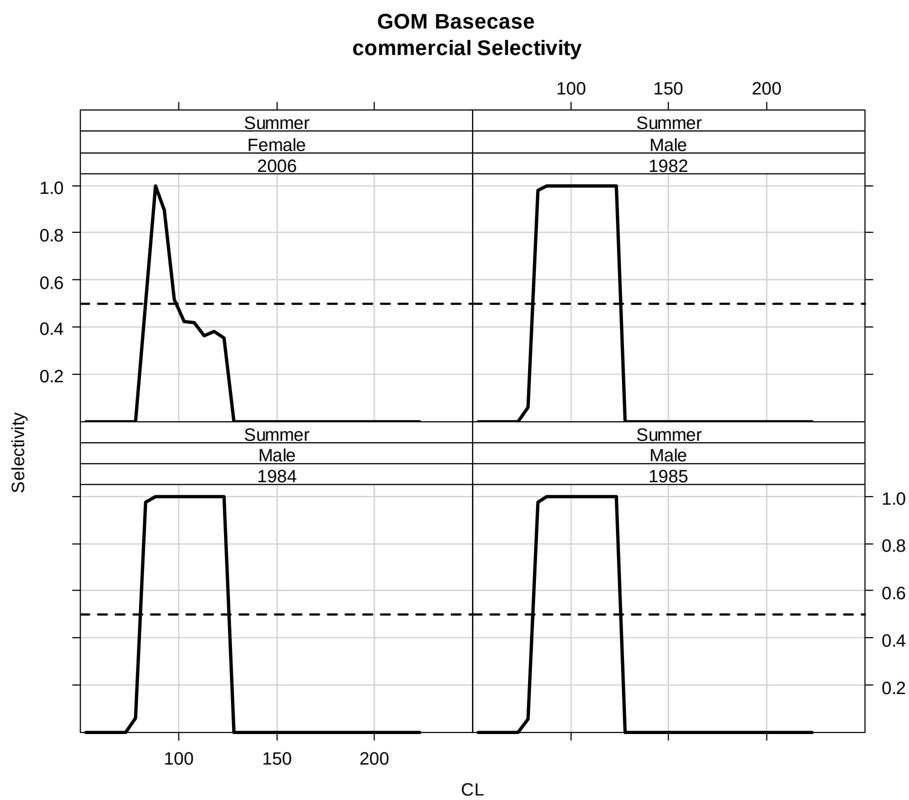
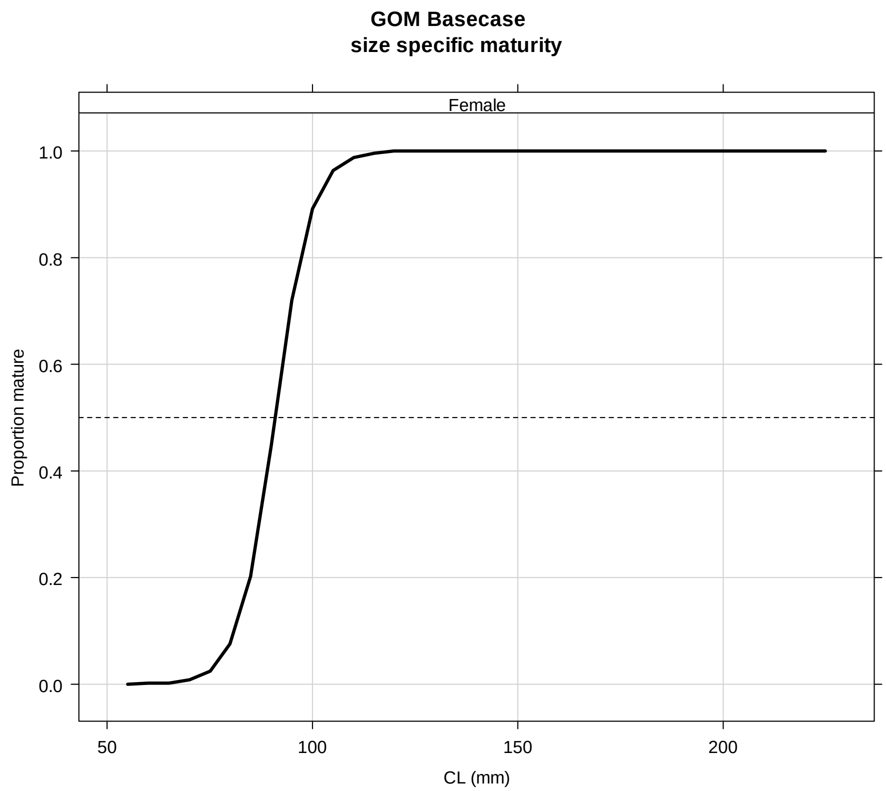


Figure 7.2.1.10. Maturity at length for female (above) and male (below) lobster in the GOM basecase model.



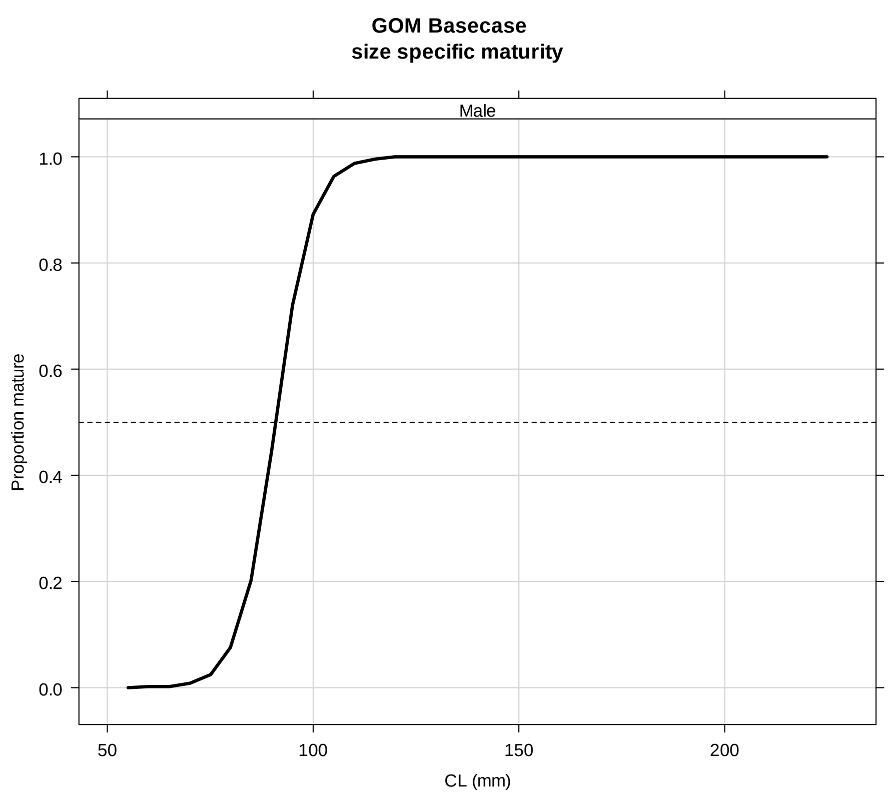


Figure 7.2.1.11. Survey selectivity curves for NEFSC fall bottom trawl (Survey 1), ME DMR (Survey 2), and MA DMF (Survey 3) estimated (NEFSC & MA DMF) or specified (ME DMR) in the GOM basecase model.

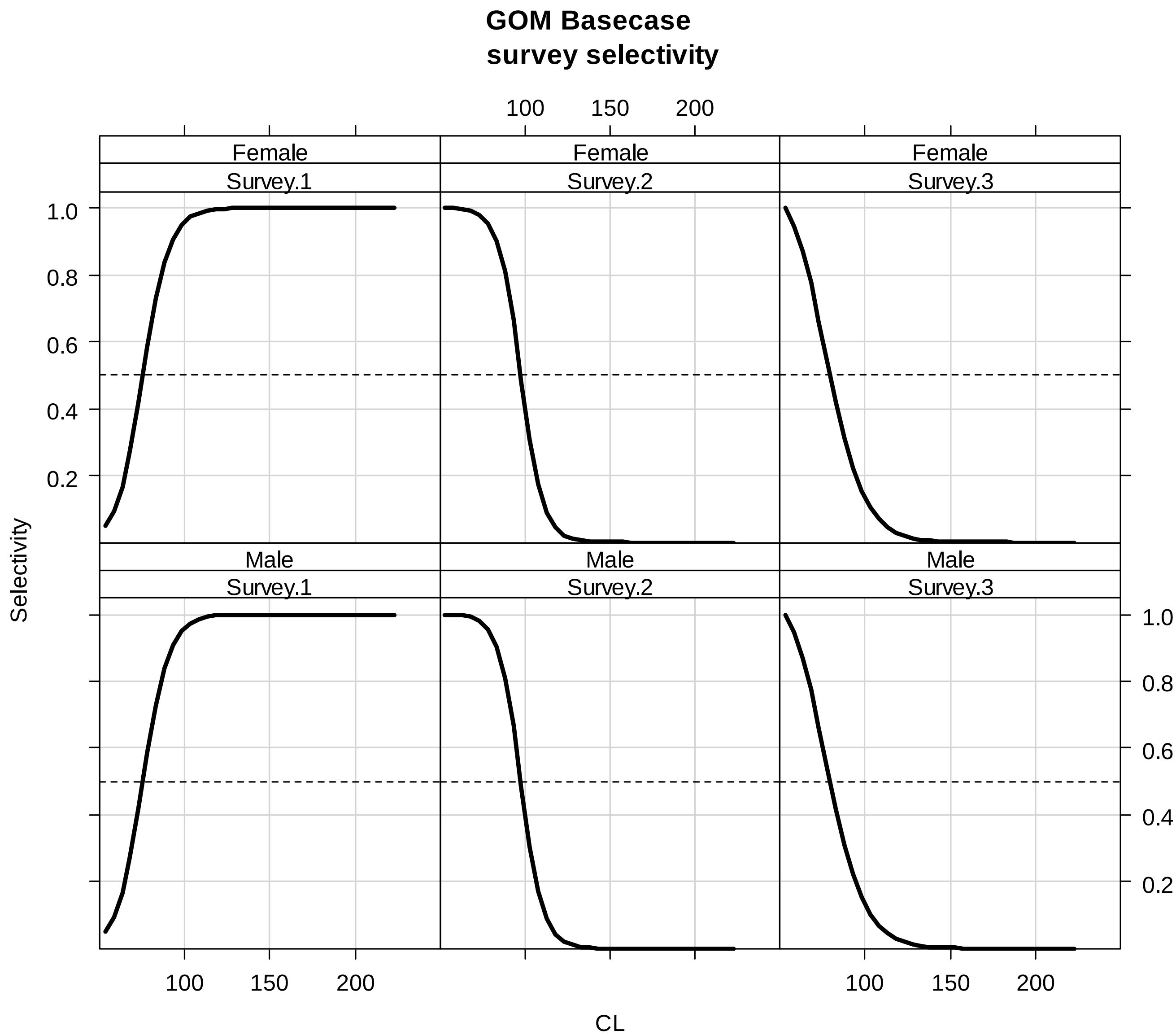


Figure 7.2.1.12. Annual effective exploitation rate (top left), reference abundance (top right), and female spawning biomass (bottom) with associated trend based reference point (median 1982-2003) and status measure (mean 2005-2007) from the basecase model for GOM.

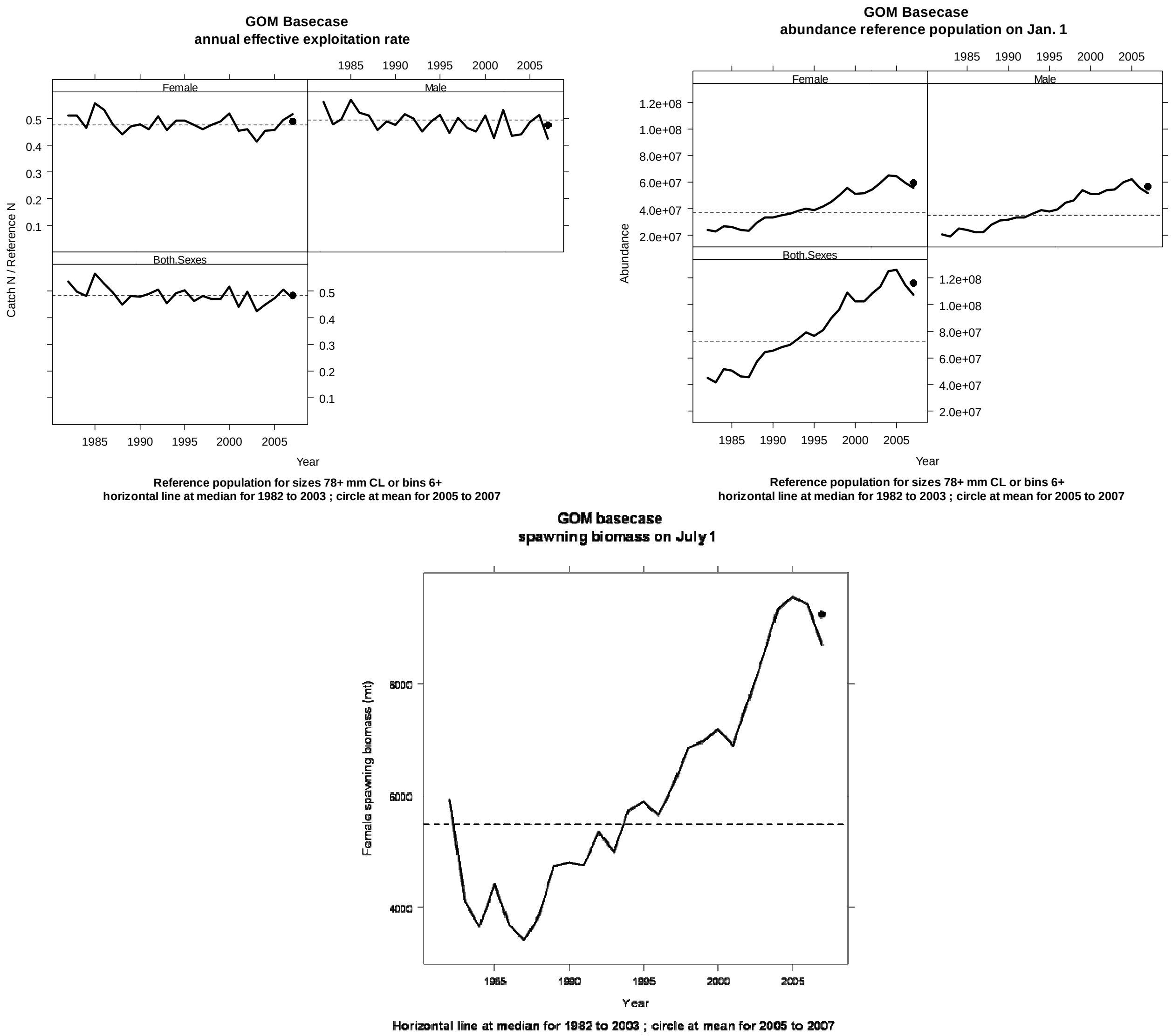


Figure 7.2.1.13. Recruitment estimates from the basecase model for GOM.

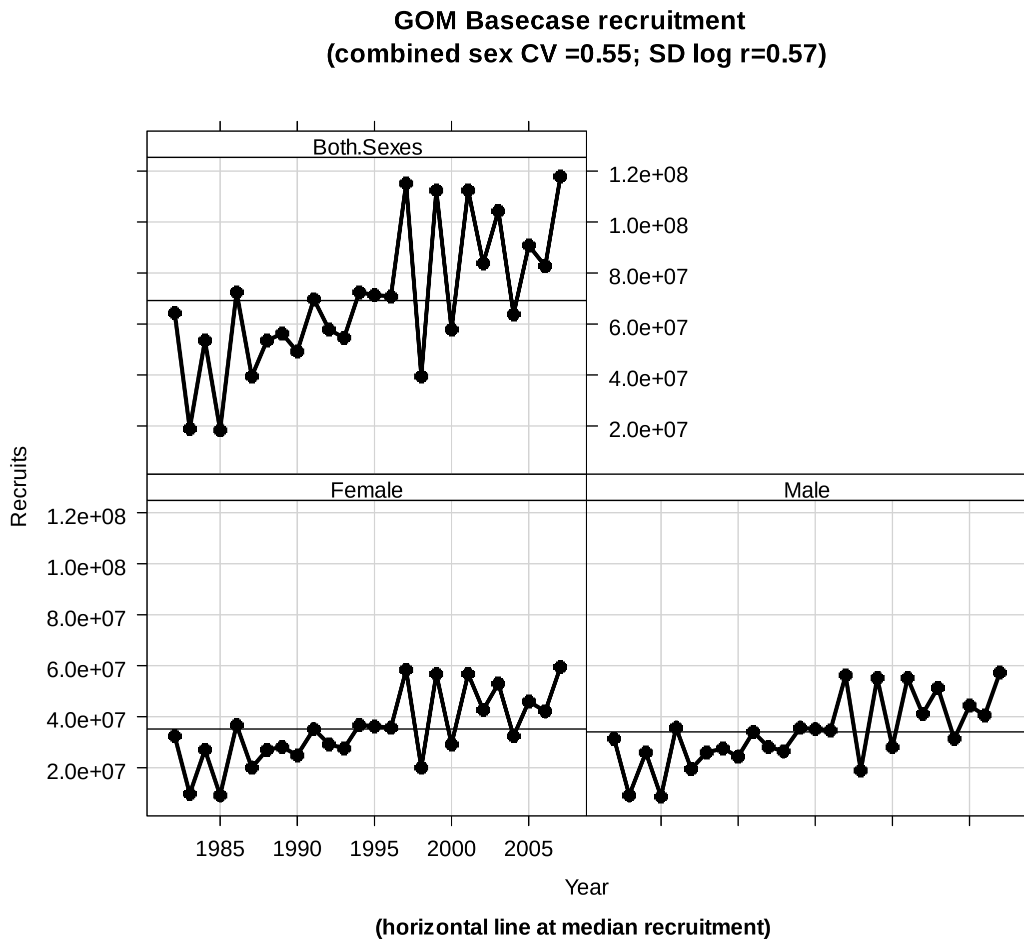


Figure 7.2.2.1. Diagnostics for survey trend data in the GBK basecase model. Plots labeled “Female” are for females and males combined.

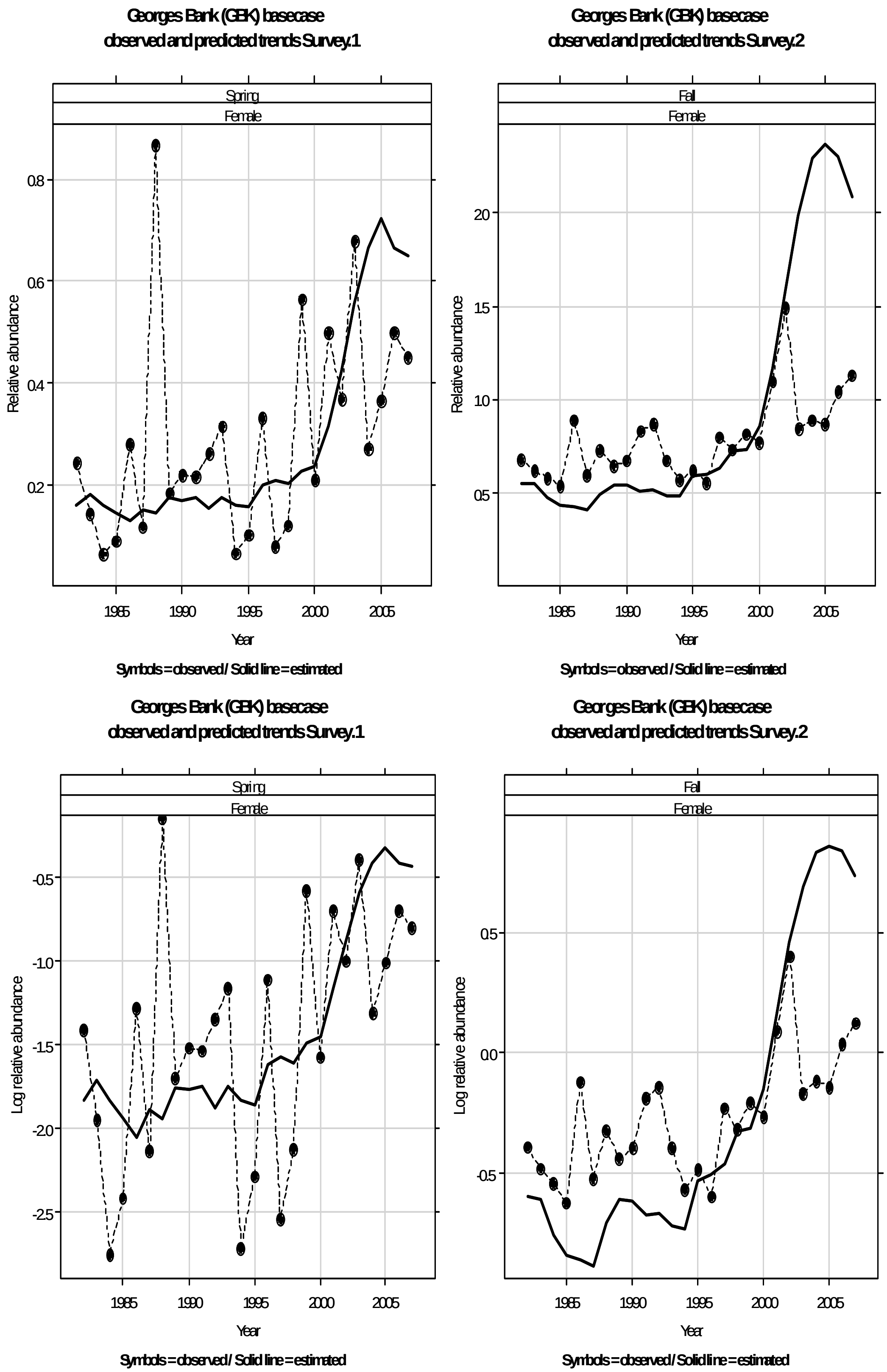


Figure 7.2.2.1. Continued. Diagnostics for survey trend data in the GBK basecase model. Plots labeled "Female" are for females and males combined.

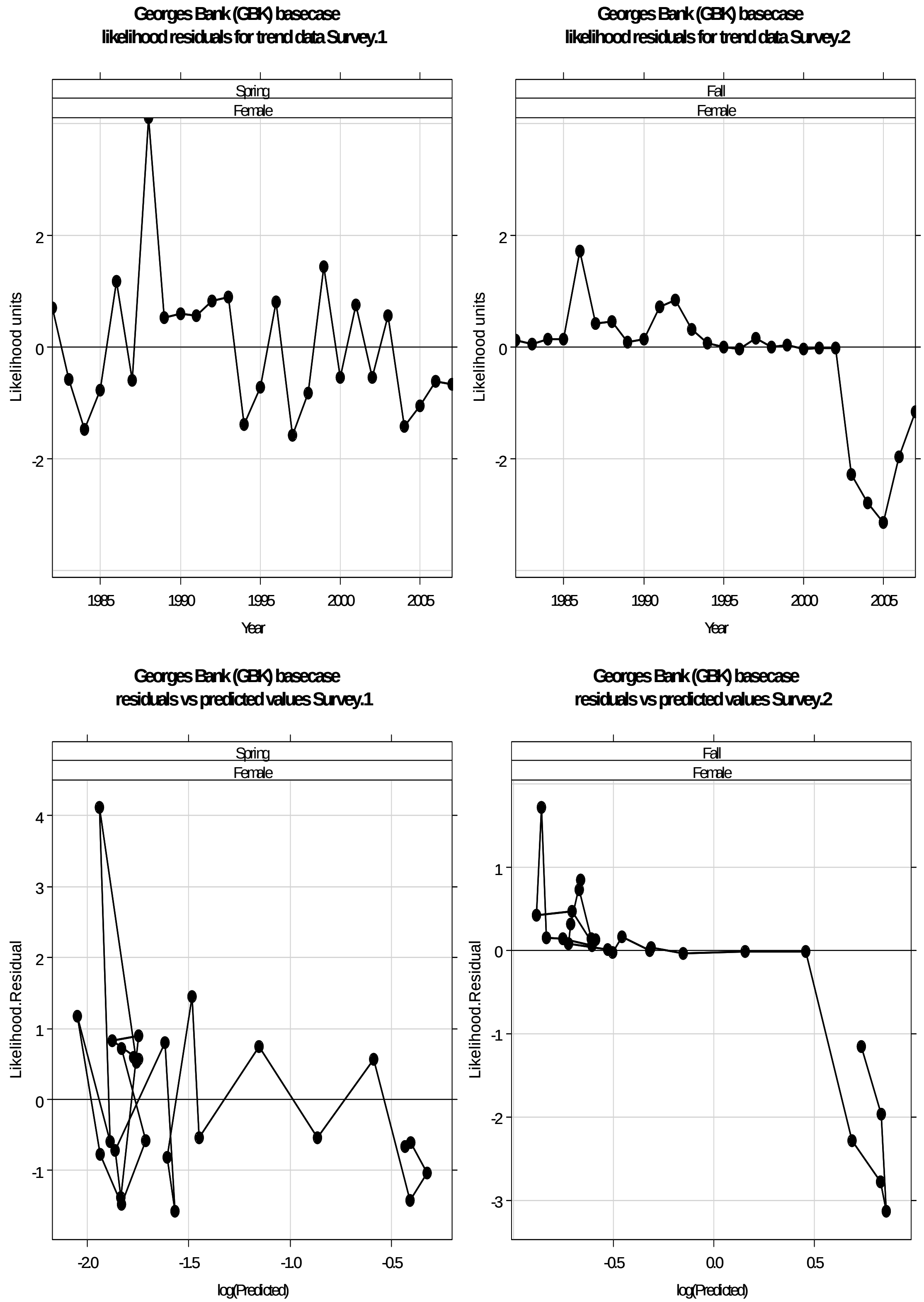


Figure 7.2.2.2. Likelihood residuals for survey length data in the GBK basecase model. Plots labeled “Female” are for females and males combined.

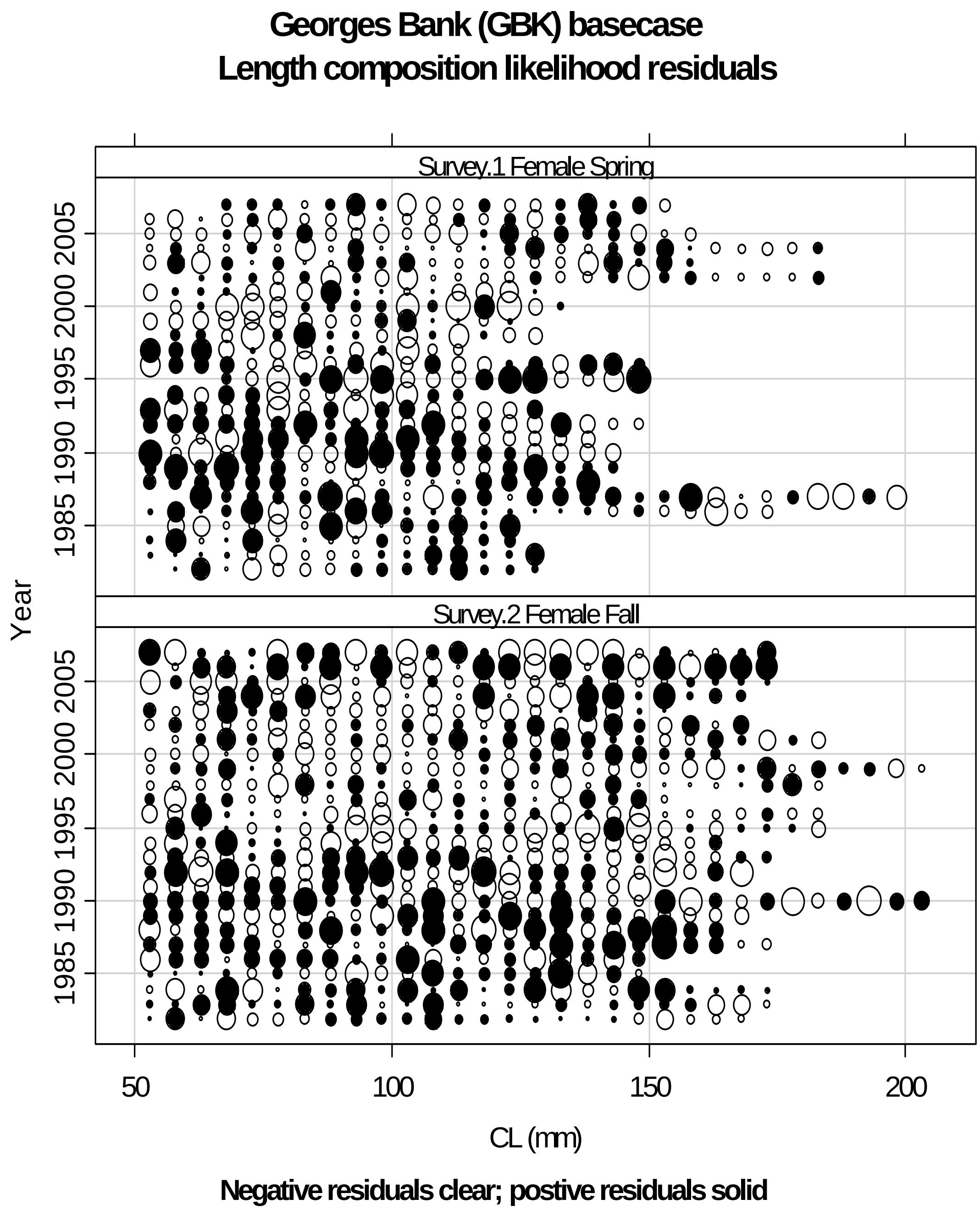


Figure 7.2.2.3. Likelihood residuals for commercial length data in the GBK basecase model. Plots labeled "Female" are for females and males combined. Negative residuals are shown as empty circles and positive residuals are shown as black circles.

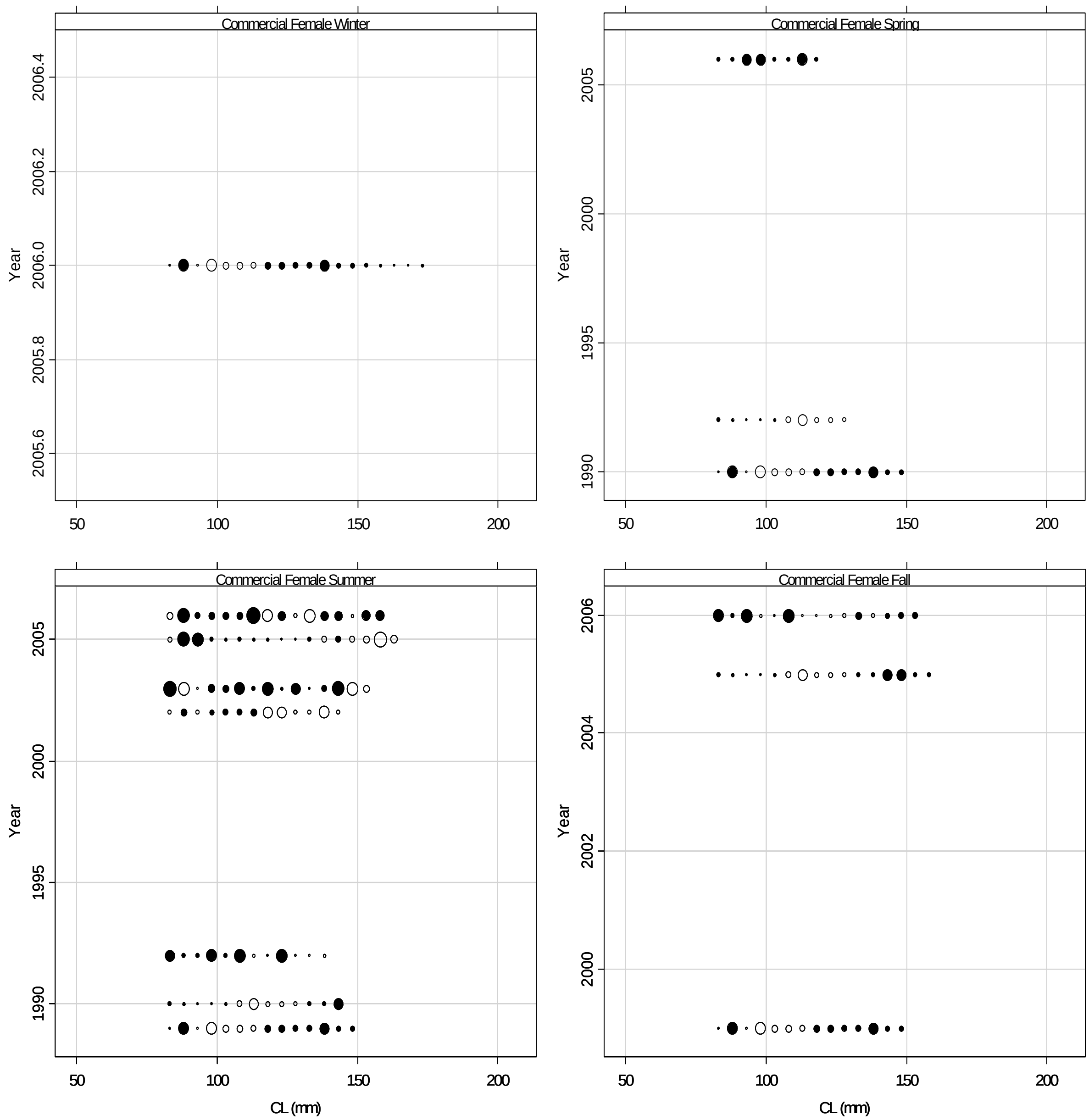


Figure 7.2.2.4. Assumed commercial selectivity curves in the basecase model for GBK during 1982 (first year in model; left-most line) and 2007 (last year in model; right-most line). Selectivity curves for other years were intermediate.

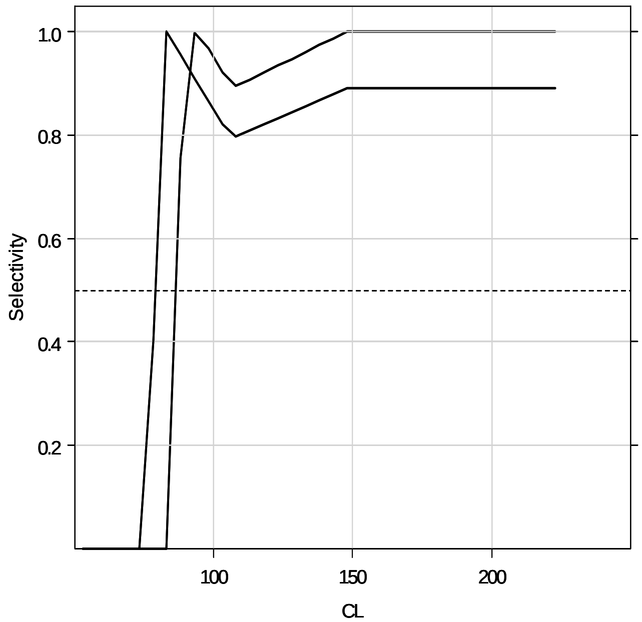


Figure 7.2.2.5. Maturity at length for female lobster in the GBK basecase model. For lack of better information, the same curve was used for males.

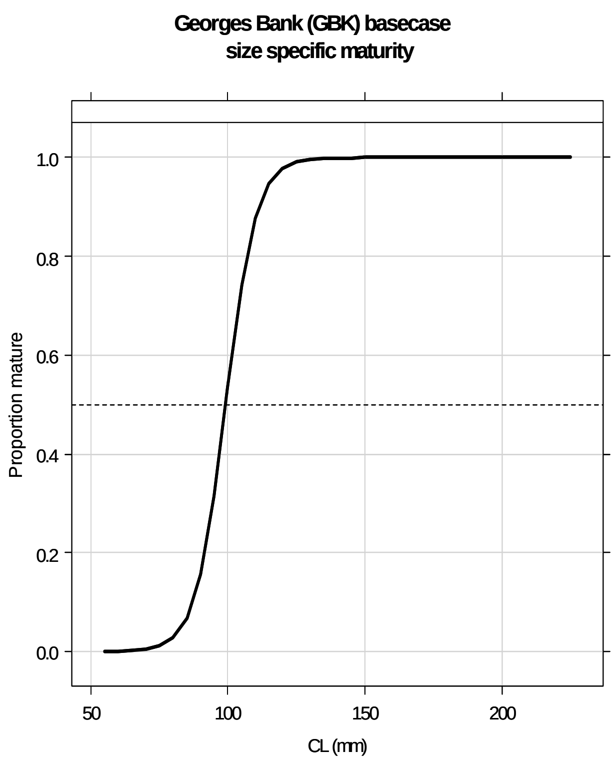


Figure 7.2.2.6. Selectivity curves for NEFSC spring and fall bottom trawl surveys estimated in the GBK basecase model.

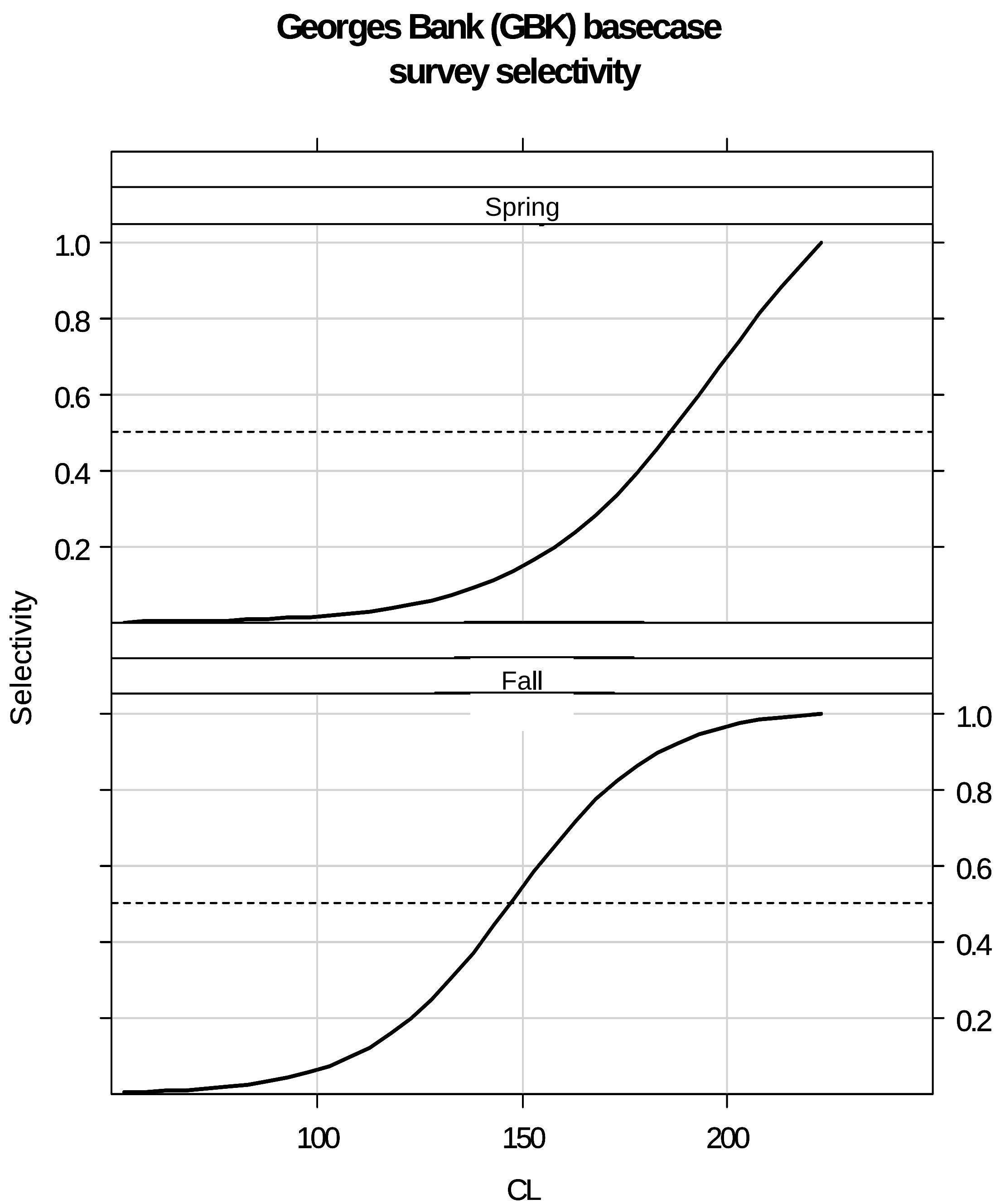


Figure 7.2.2.7. Observed (symbols) and predicted (solid line) landings by season for lobster from the GBK basecase model.
Plots labeled “Female” are for females and males combined.

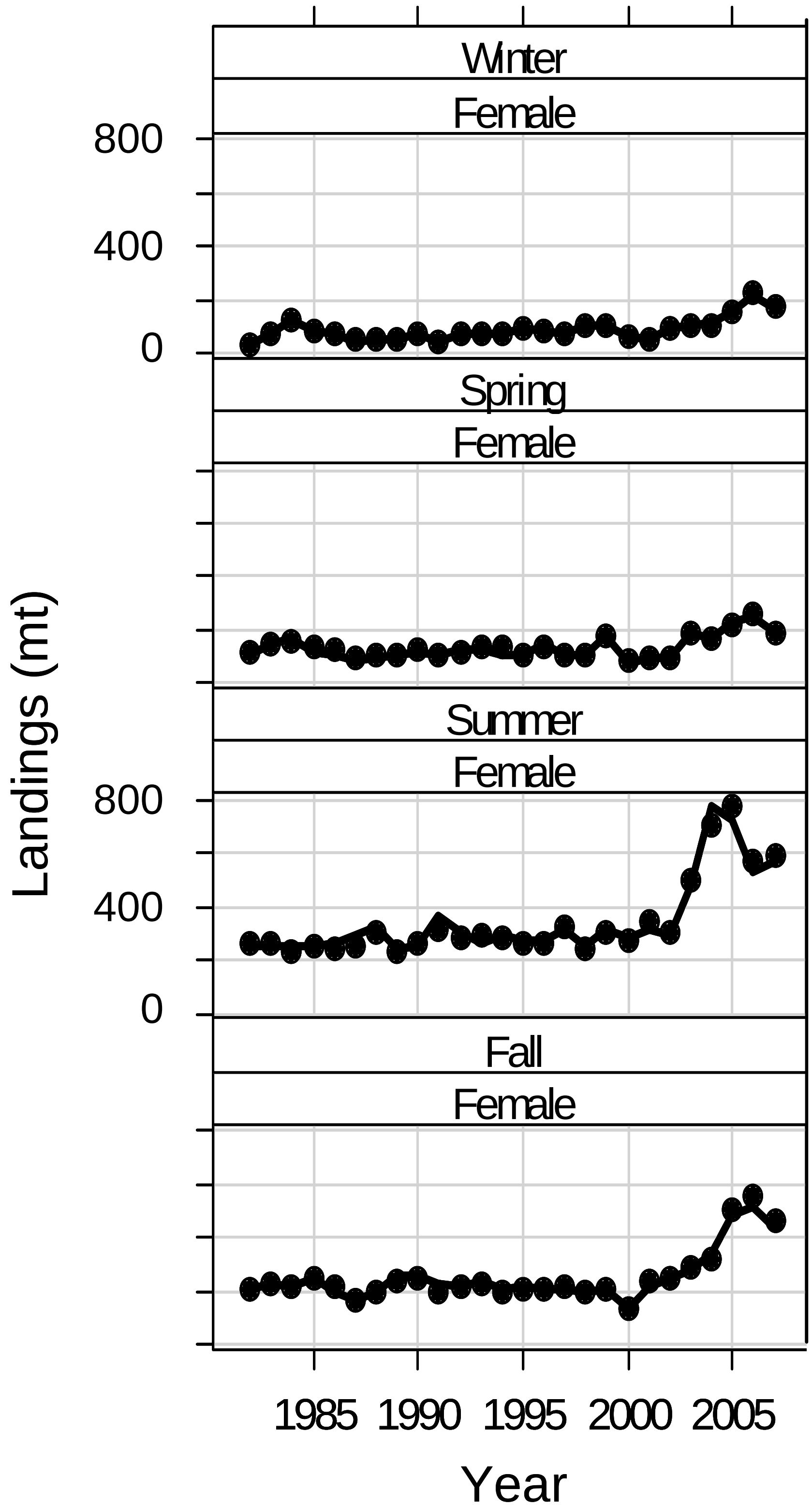


Figure 7.2.2.8. Landings data for male and female lobster for GBK in units of weight (top) and numbers (bottom).

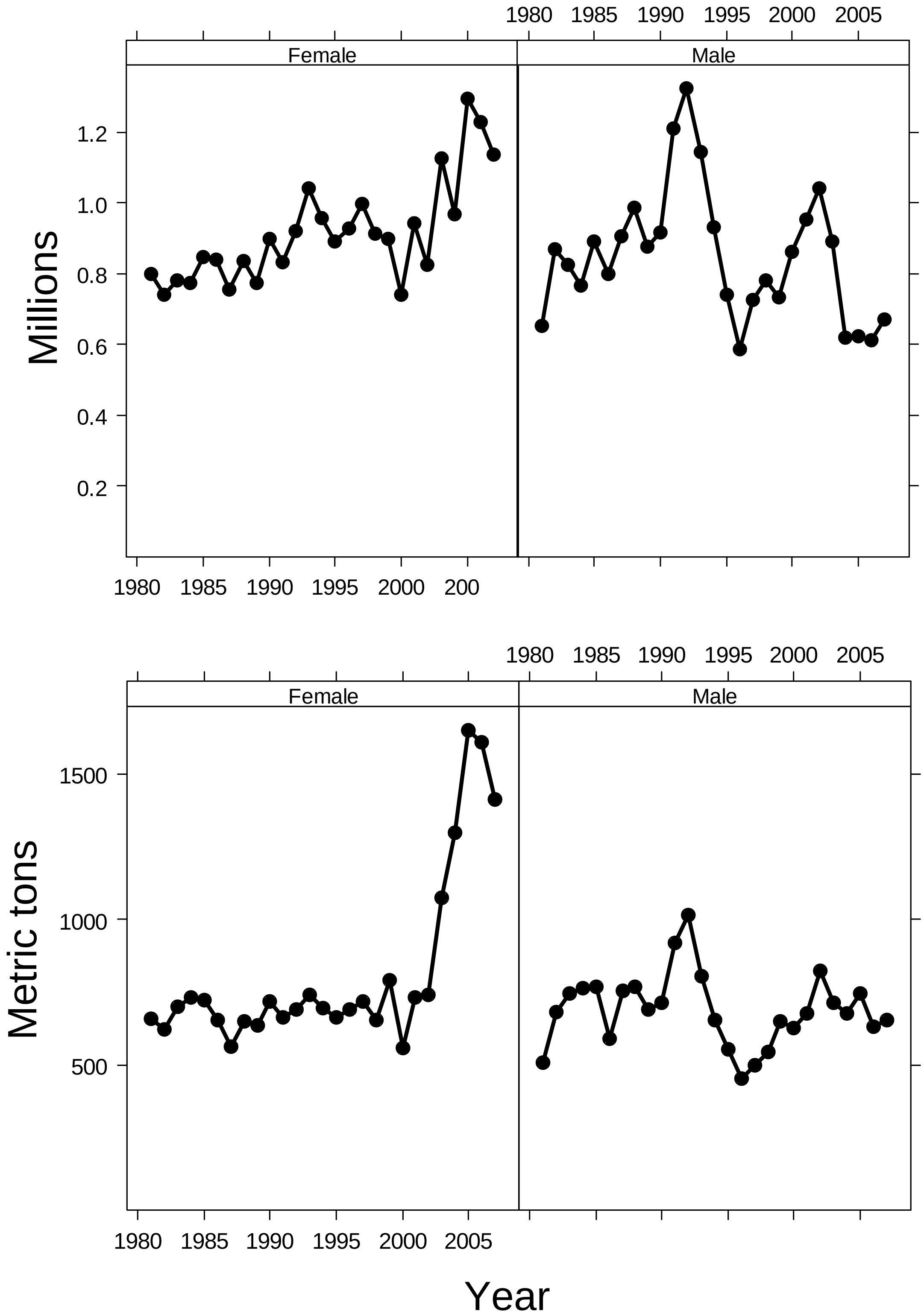


Figure 7.2.2.9. Survey catch data (delta mean numbers per tow) for lobster in NESFC spring and fall bottom trawl surveys.

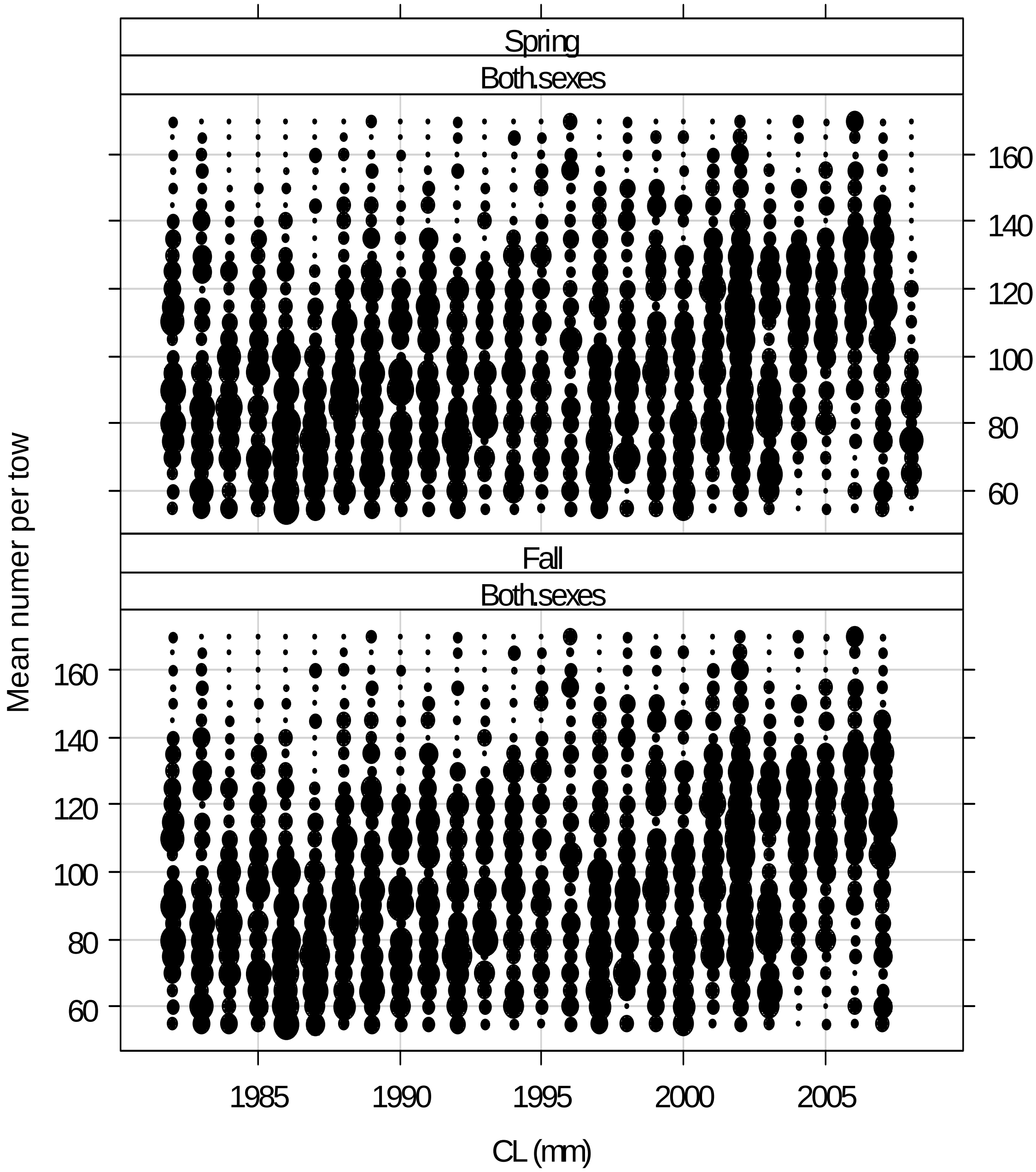


Figure 7.2.2.10. Annual effective exploitation rate with associated trend based reference point (median 1982-2003) and status measure (mean 2005-2007) from the basecase model for GBK.

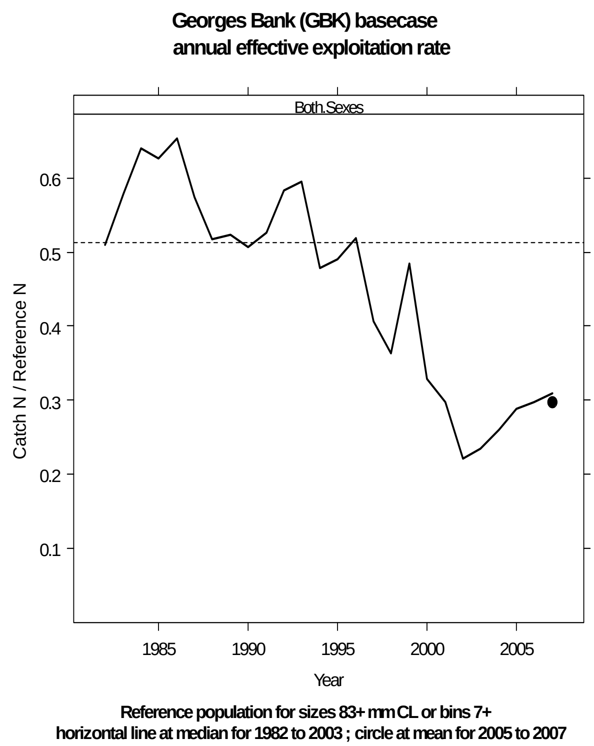


Figure 7.2.2.11. Reference abundance with associated trend based reference point (median 1982-2003) and status measure (mean 2005-2007) from the basecase model for GBK.

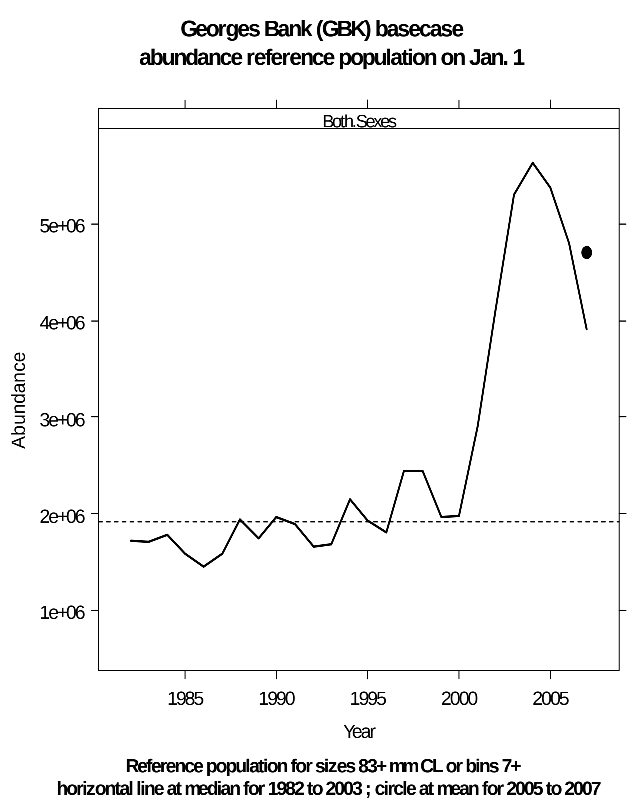


Figure 7.2.2.12. Female spawning biomass with associated trend based reference point (median 1982-2003) and status measure (mean 2005-2007) from the basecase model for GBK. The scale is approximate because 50% of the estimated biomass was assumed to be female. This assumption does not affect the estimated trend.

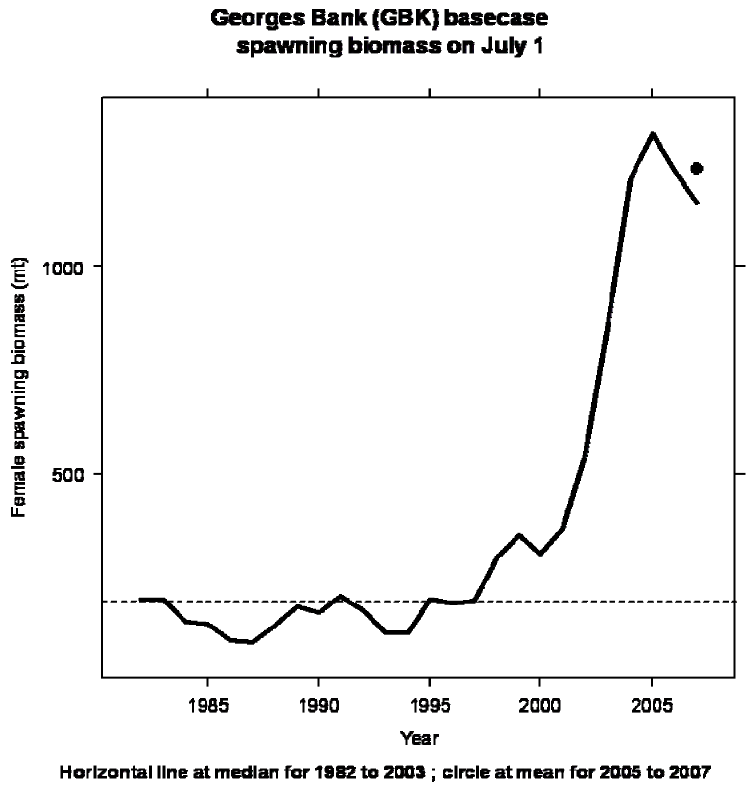


Figure 7.2.2.13. Recruitment estimates from the basecase model for GBK.

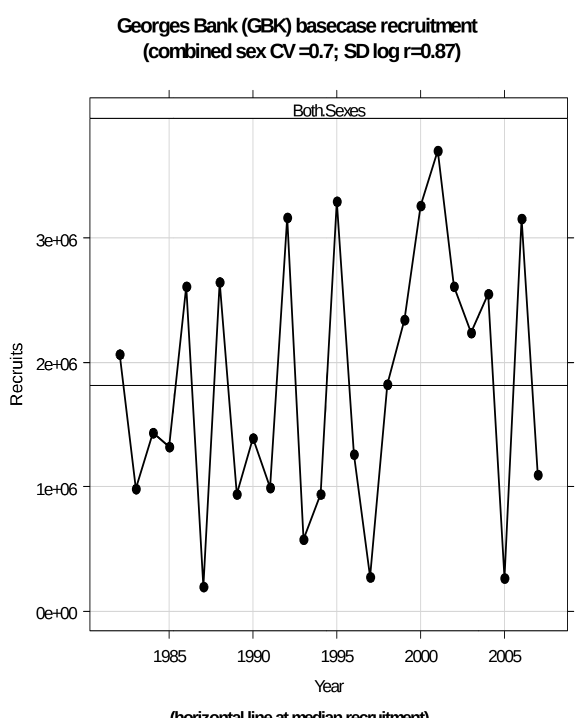


Figure 7.2.2.14. Population abundance at size estimates for female and male lobster from the GBK basecase model.
The dashed vertical lines at 100 mm CL help illustrate increases in abundance of large lobster starting in 2002.

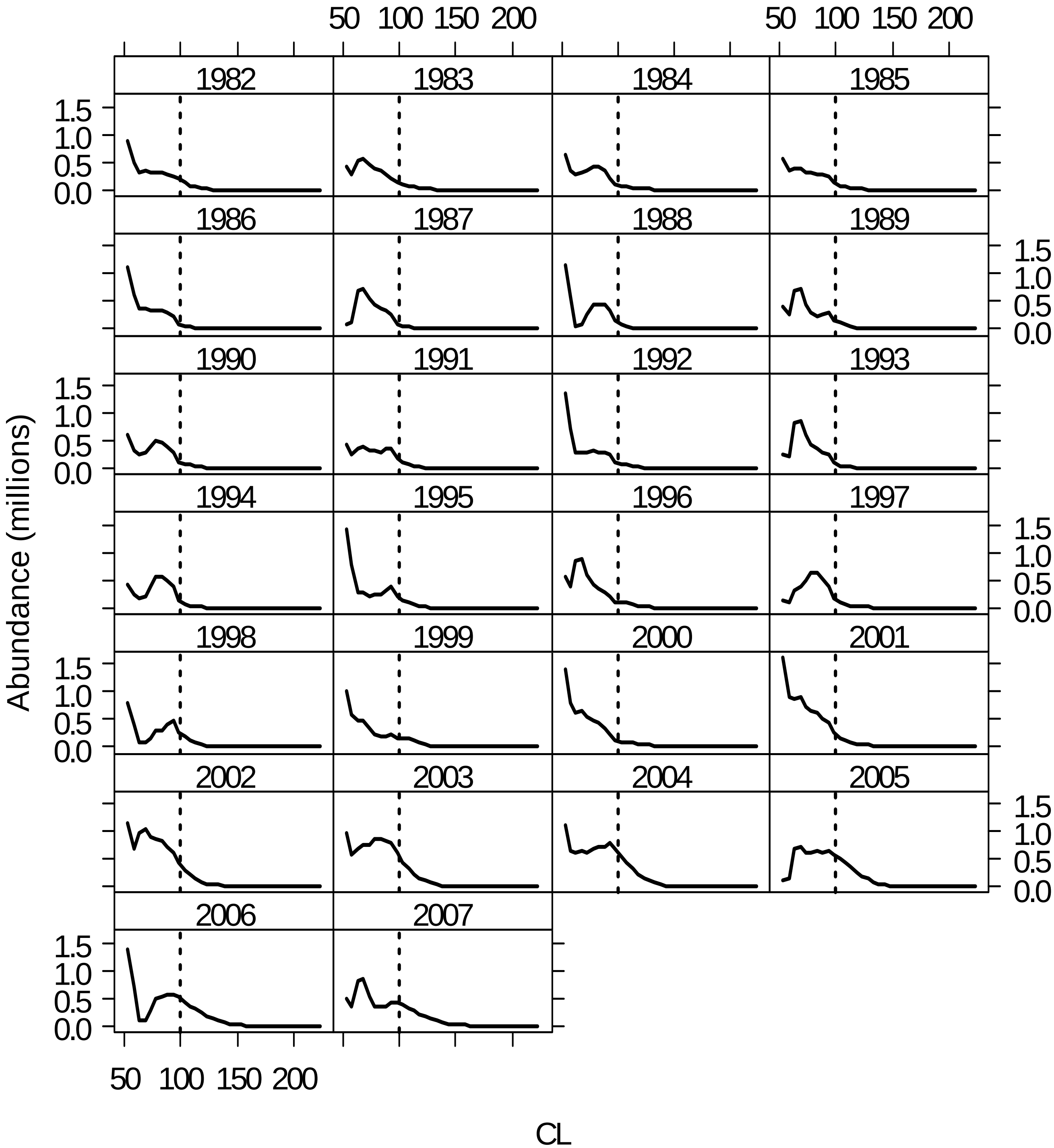
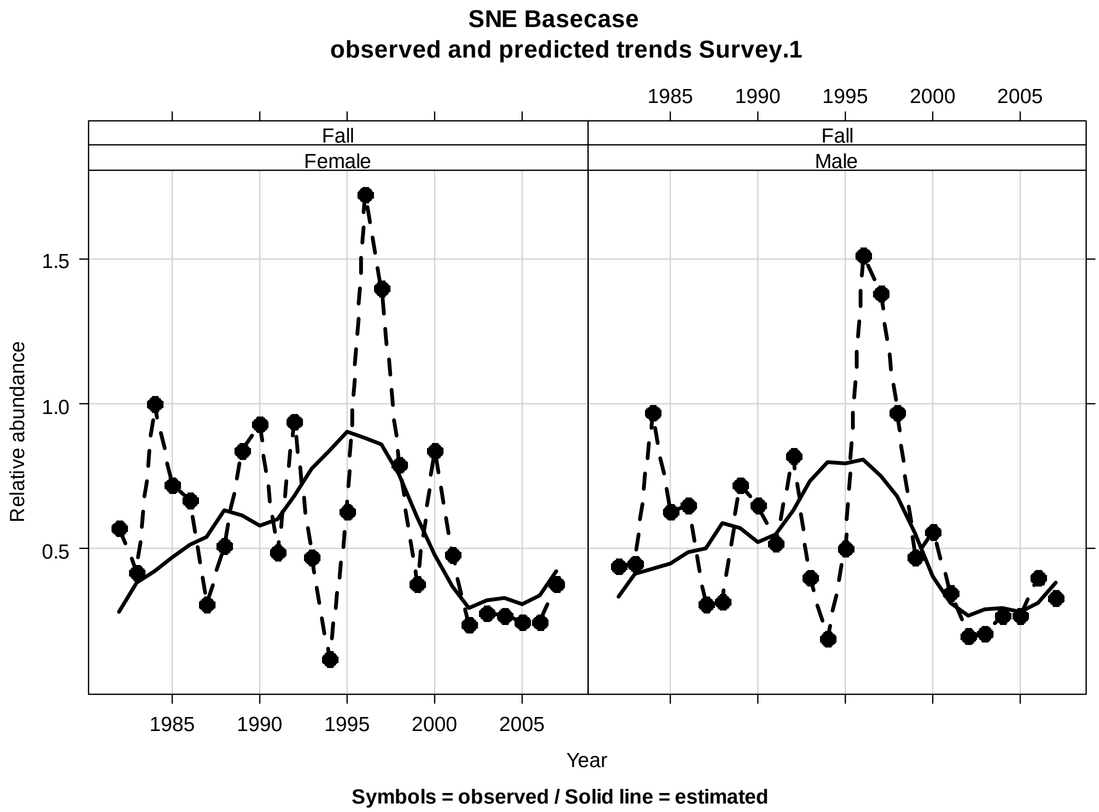


Figure 7.2.3.1. Diagnostics for NEFSC fall trawl survey trend data used in the SNE basecase model.



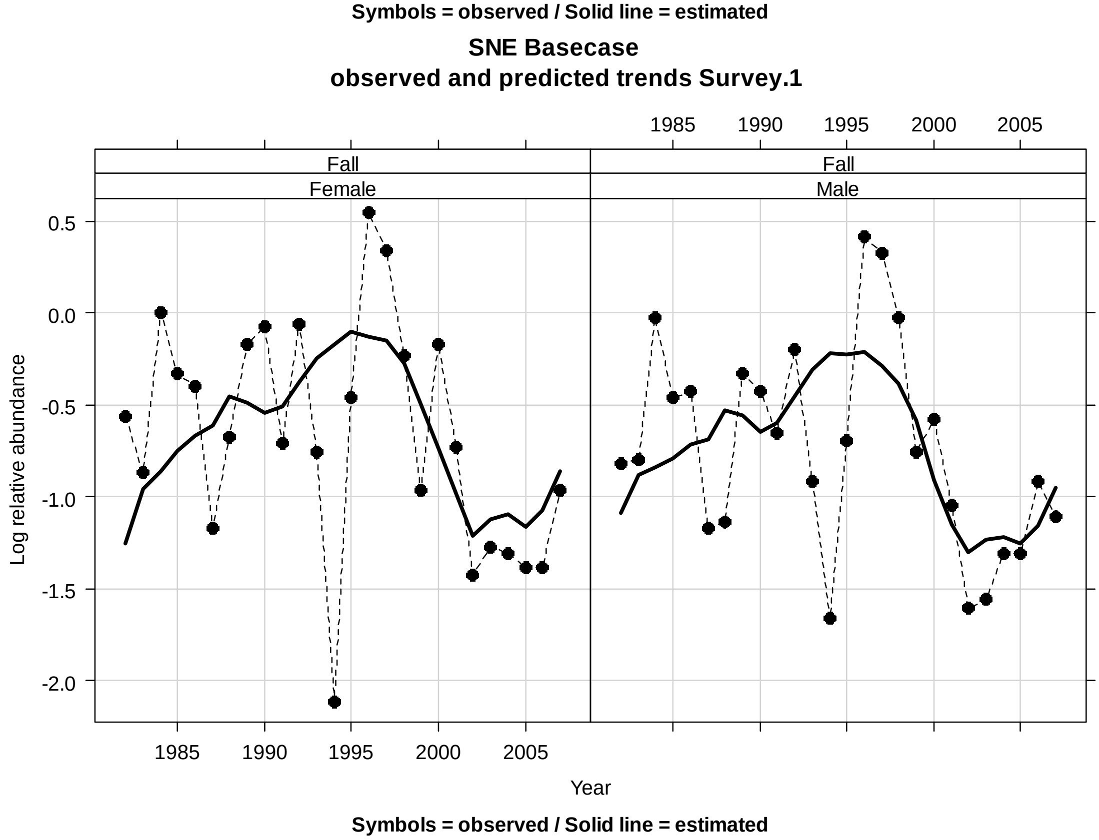
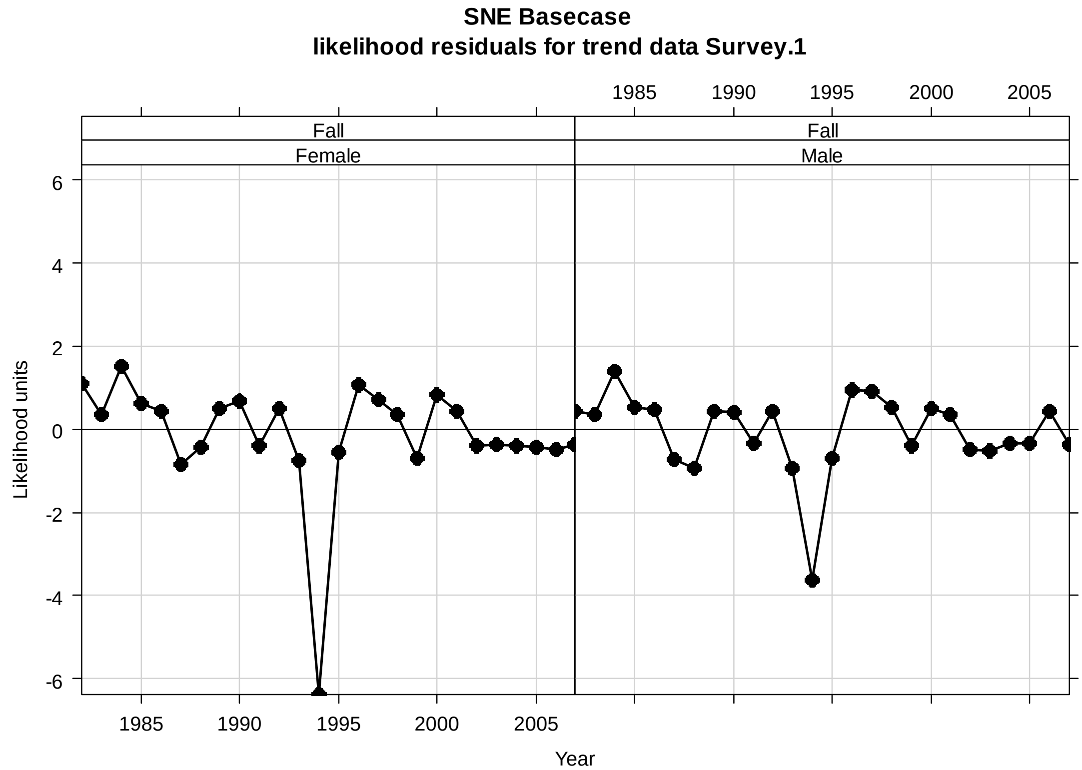


Figure 7.2.3.1. Continued. Diagnostics for NEFSC fall trawl survey trend data used in the SNE basecase model.



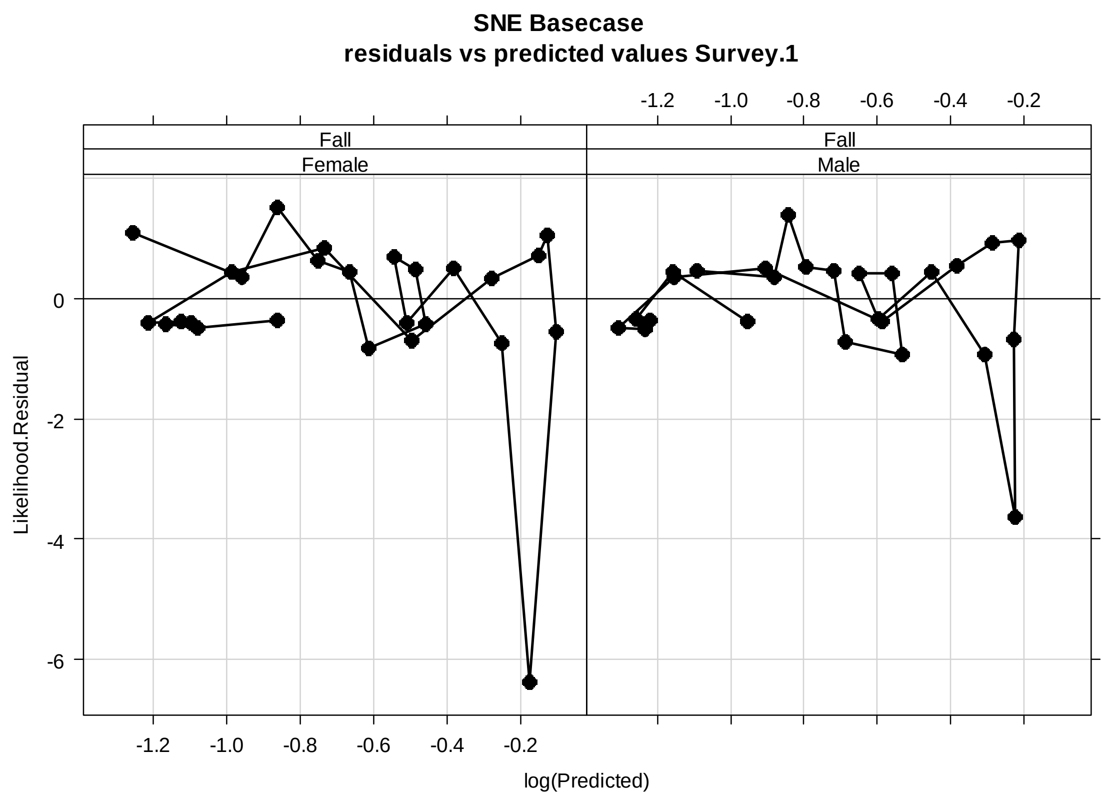
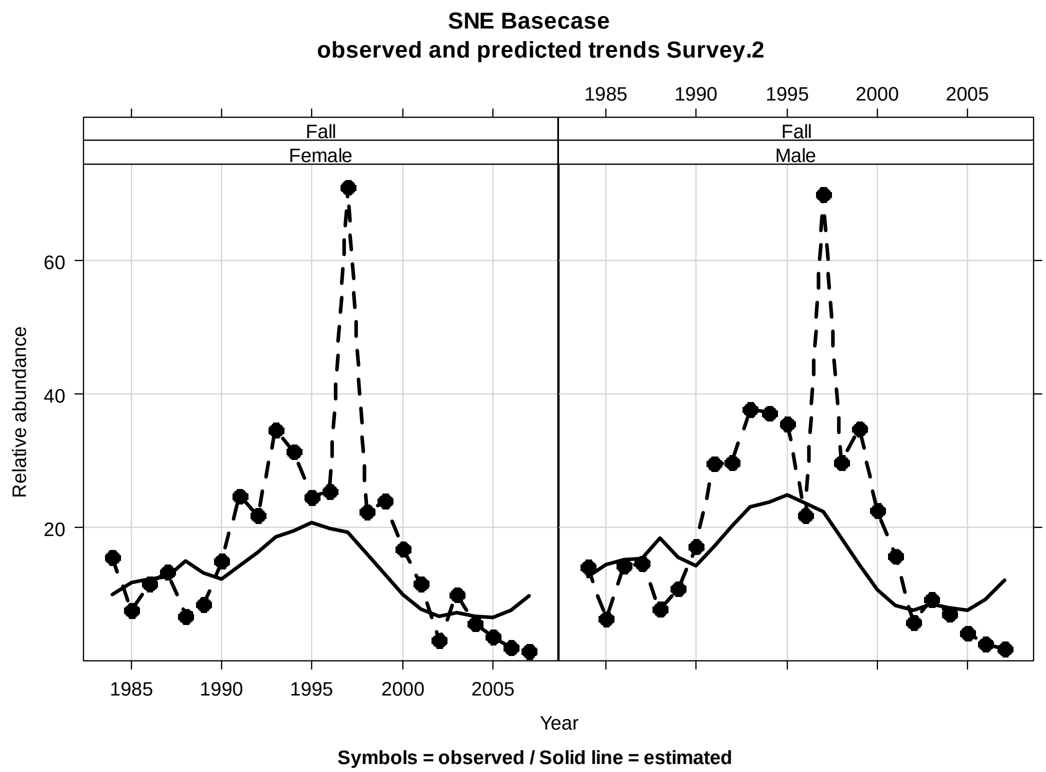


Figure 7.2.3.2. Diagnostics for CT DEP fall trawl survey trend data used in the SNE basecase model.



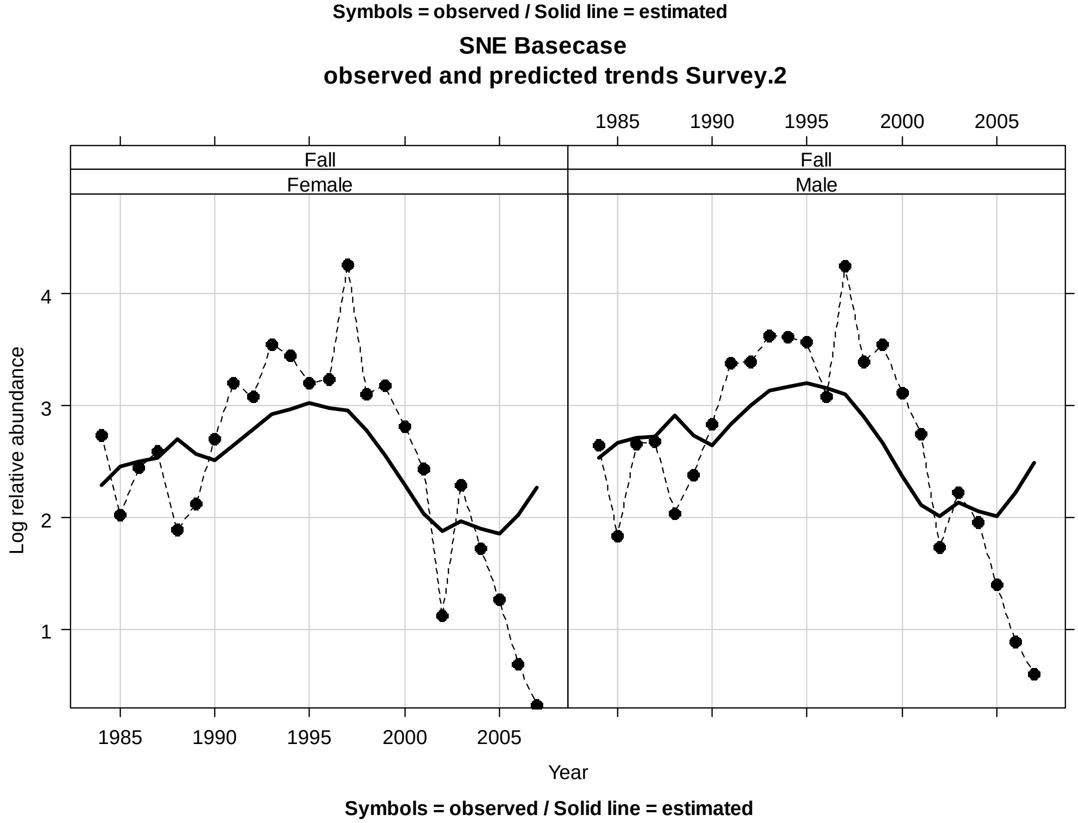
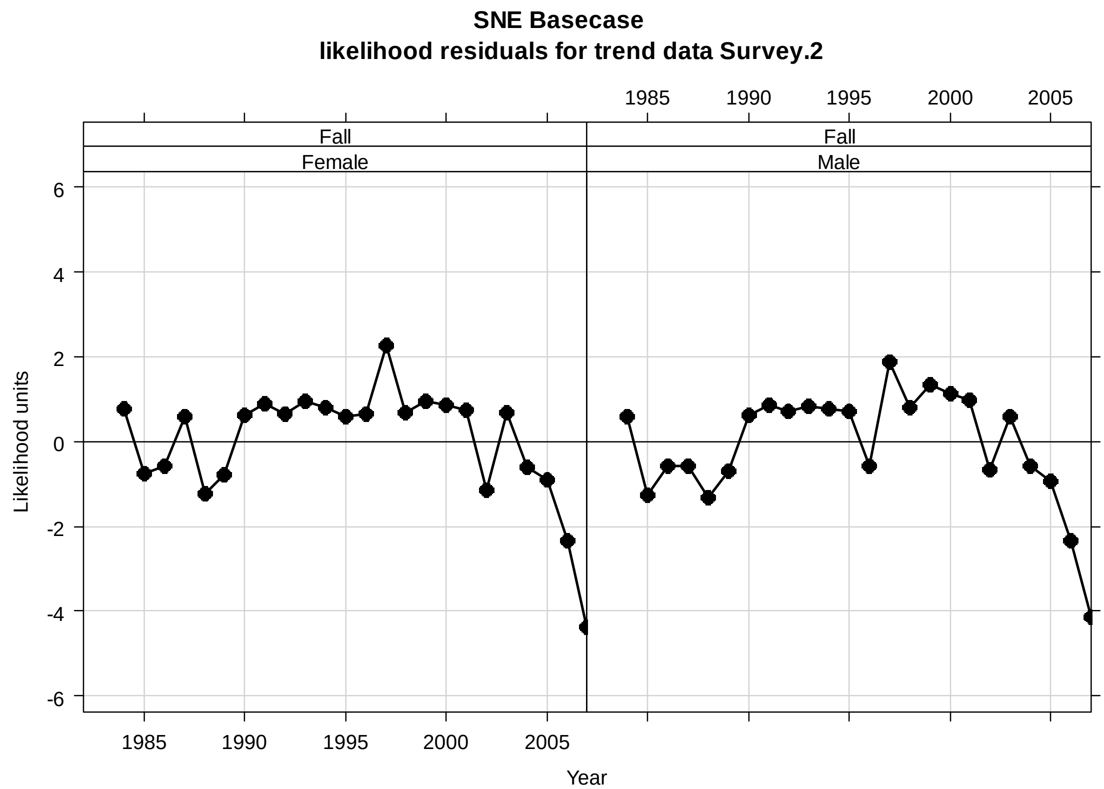


Figure 7.2.3.2. Continued. Diagnostics for CT DEP fall trawl survey trend data used in the SNE basecase model.



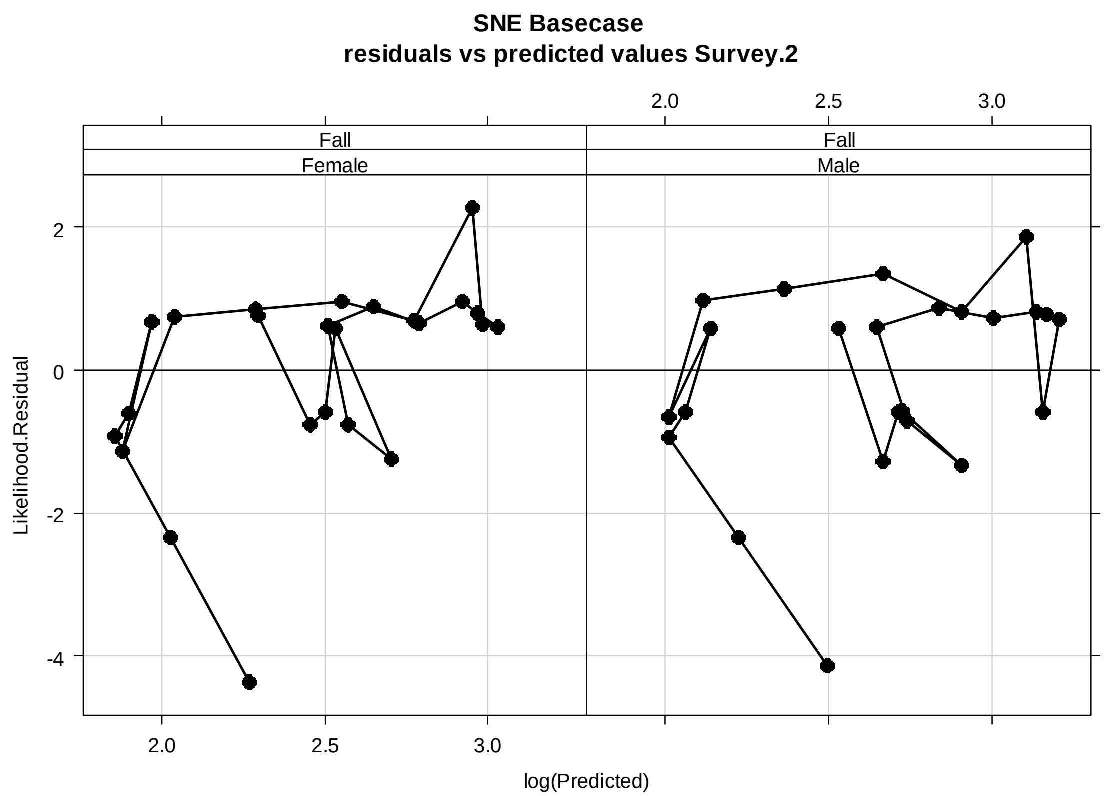
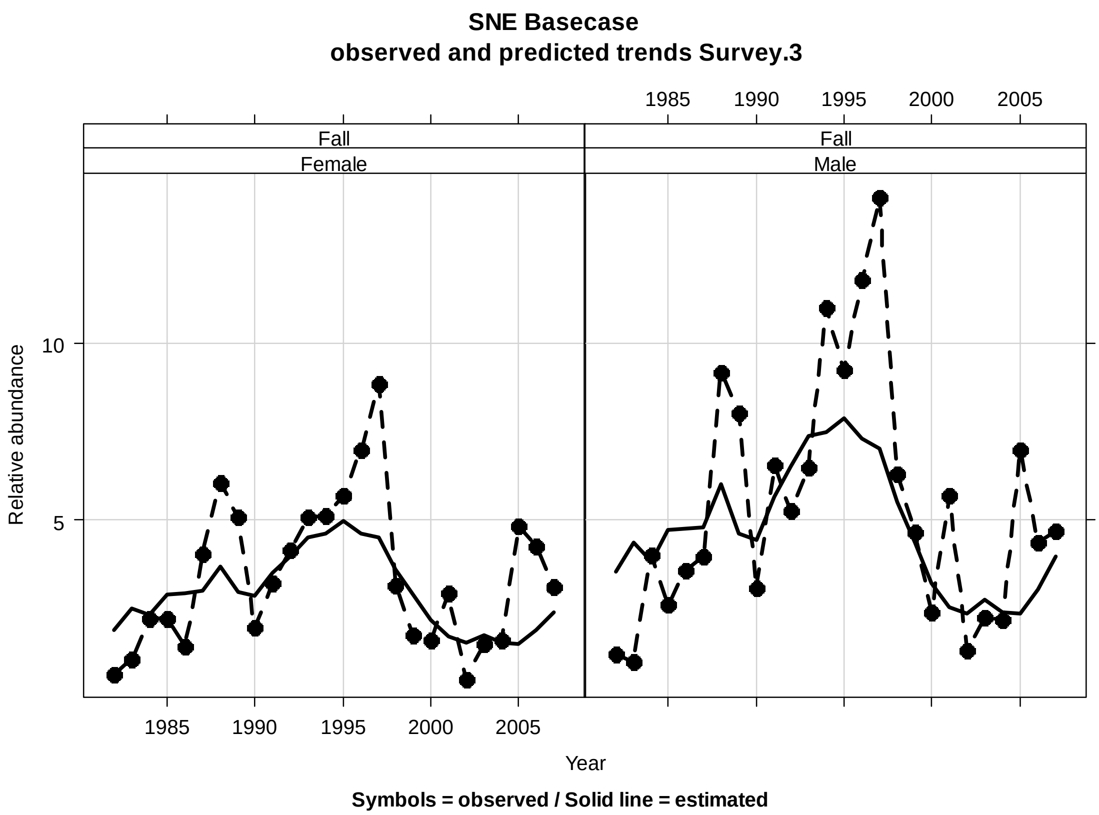


Figure 7.2.3.3. Diagnostics for RI DEM fall trawl survey trend data used in the SNE basecase model.



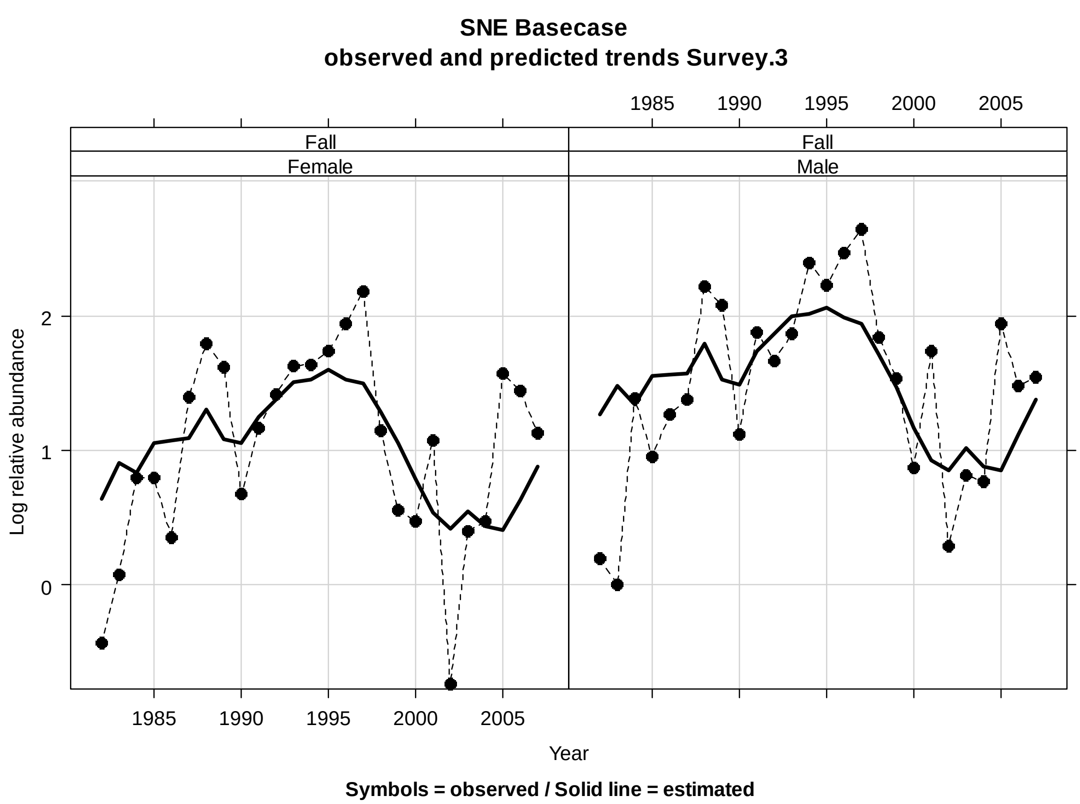
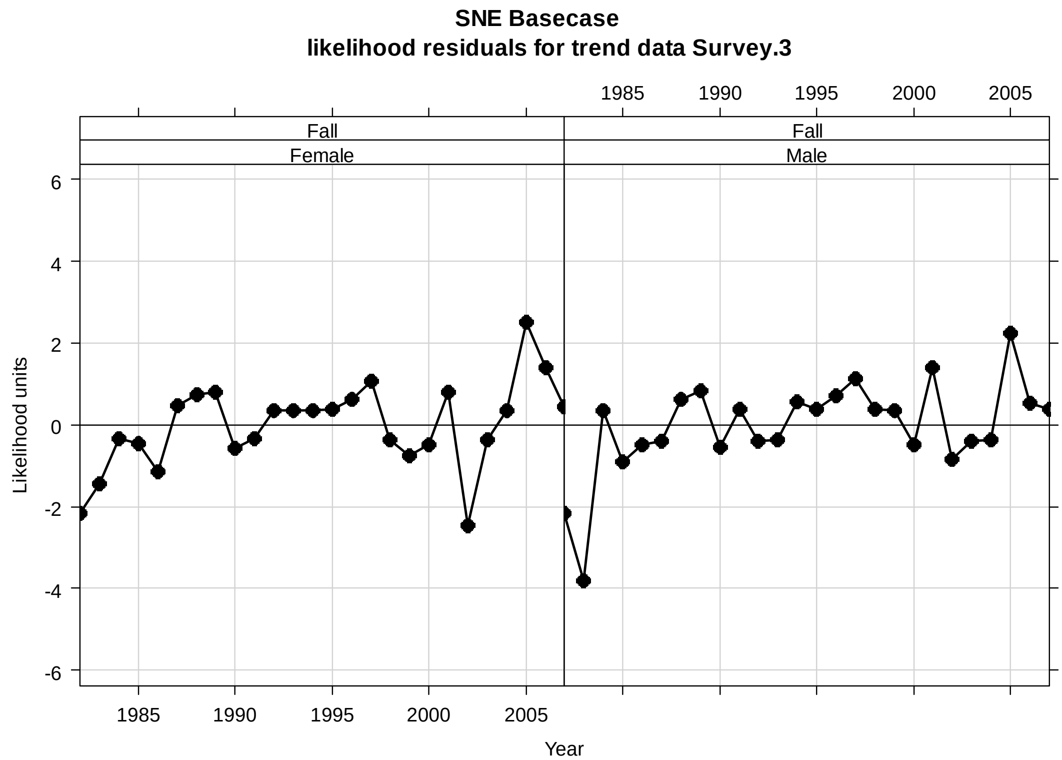


Figure 7.2.3.3. Continued. Diagnostics for RI DEM fall trawl survey trend data used in the SNE basecase model.



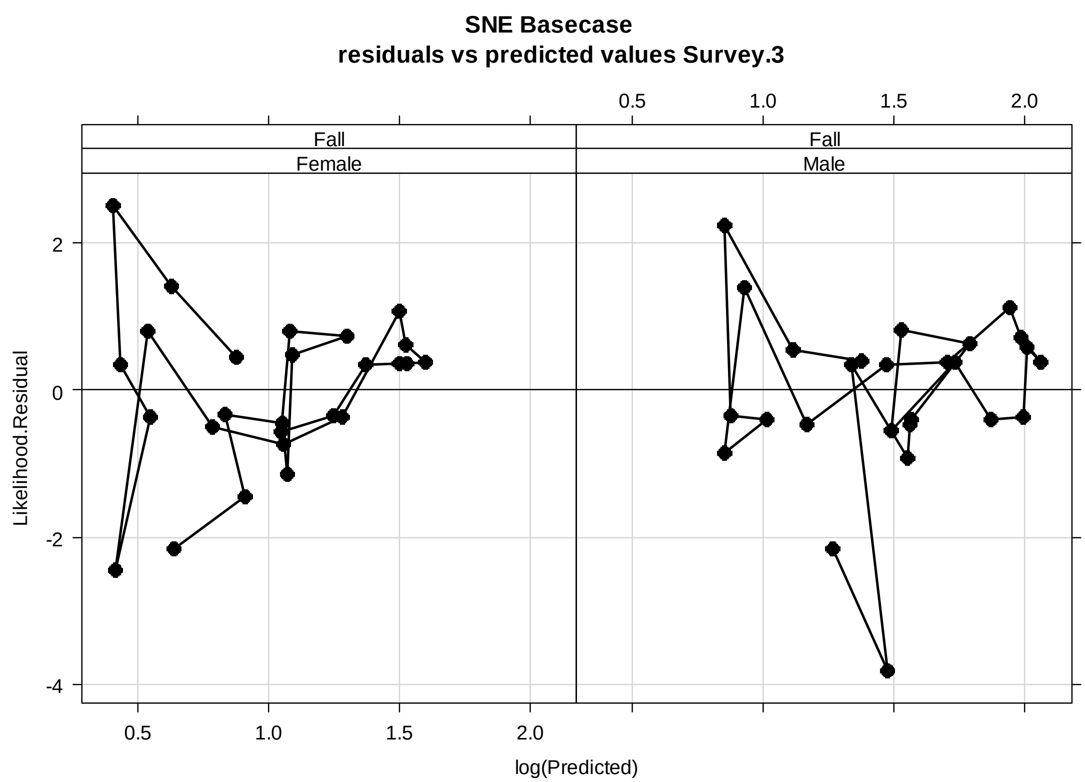


Figure 7.2.3.4. Observed and predicted landings by season (above) and annually (below) for lobster from the SNE basecase model.

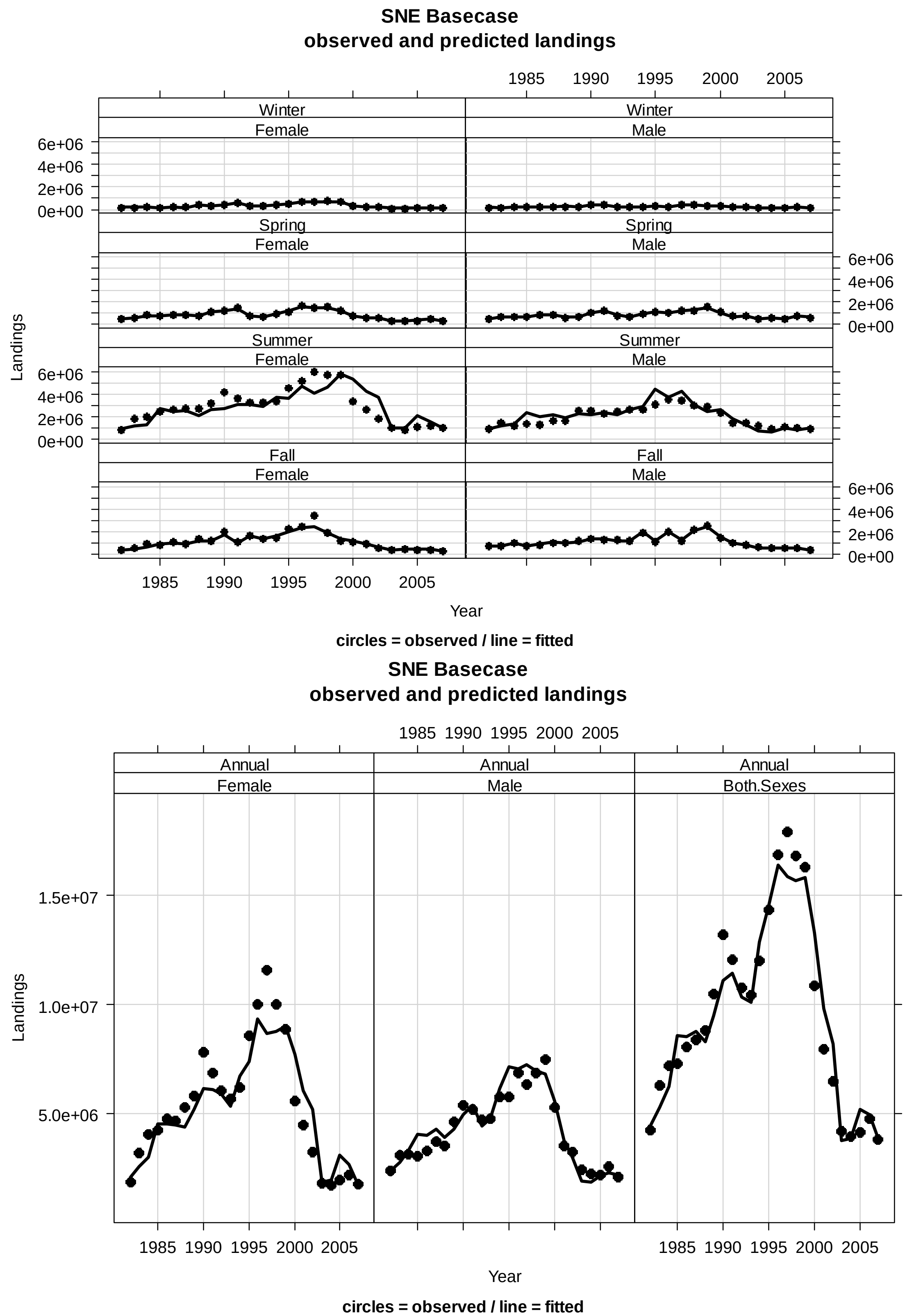


Figure 7.2.3.5. Example graphs of observed and predicted female catch at length data from the basecase model for GOM: A) Commercial B) NEFSC fall survey C) CT DEP fall survey D) RI DEM fall survey.

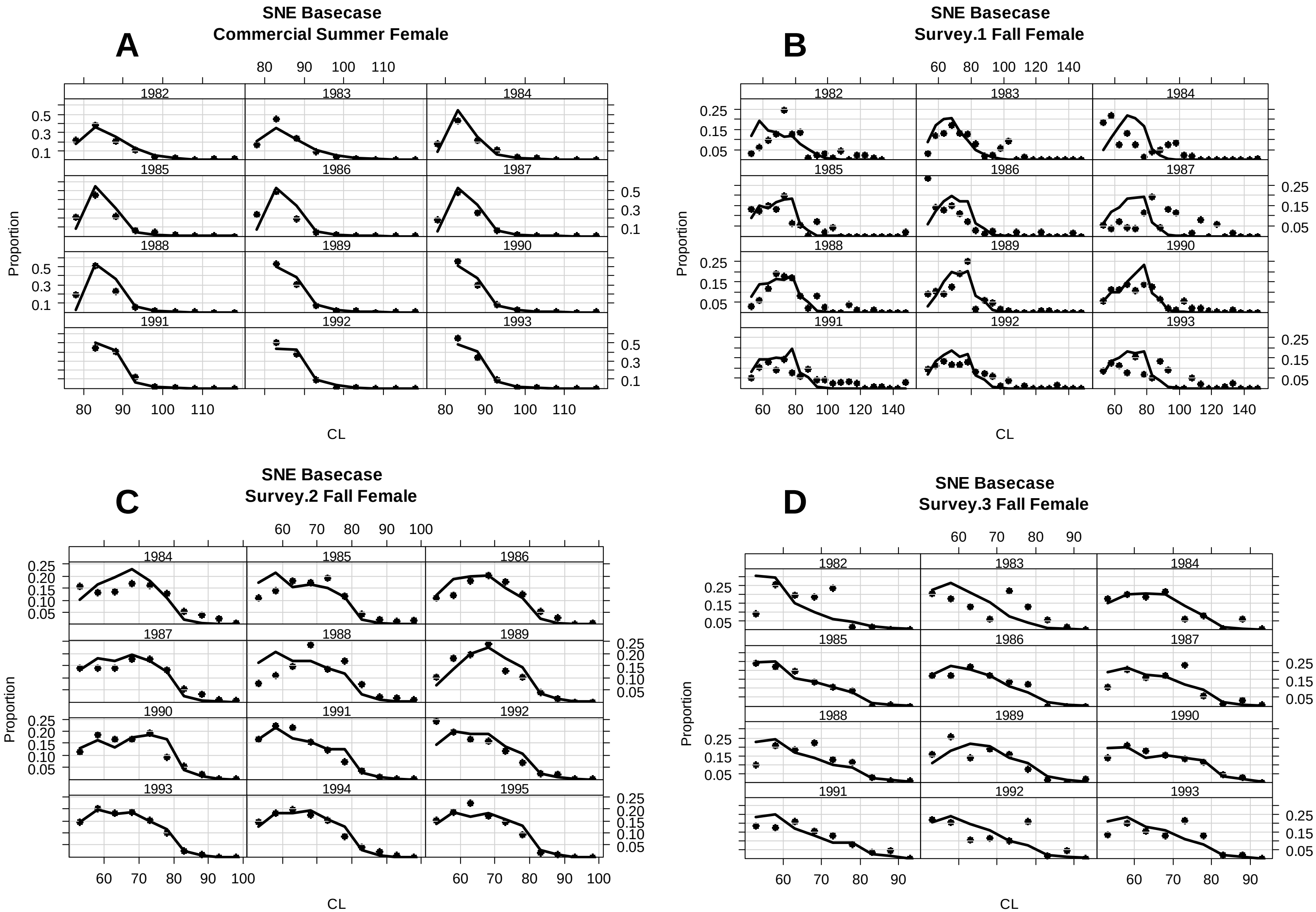


Figure 7.2.3.6. Example graphs of observed and predicted male catch at length data from the basecase model for GOM: A) Commercial B) NEFSC fall survey C) CT DEP fall survey D) RI DEM fall survey.

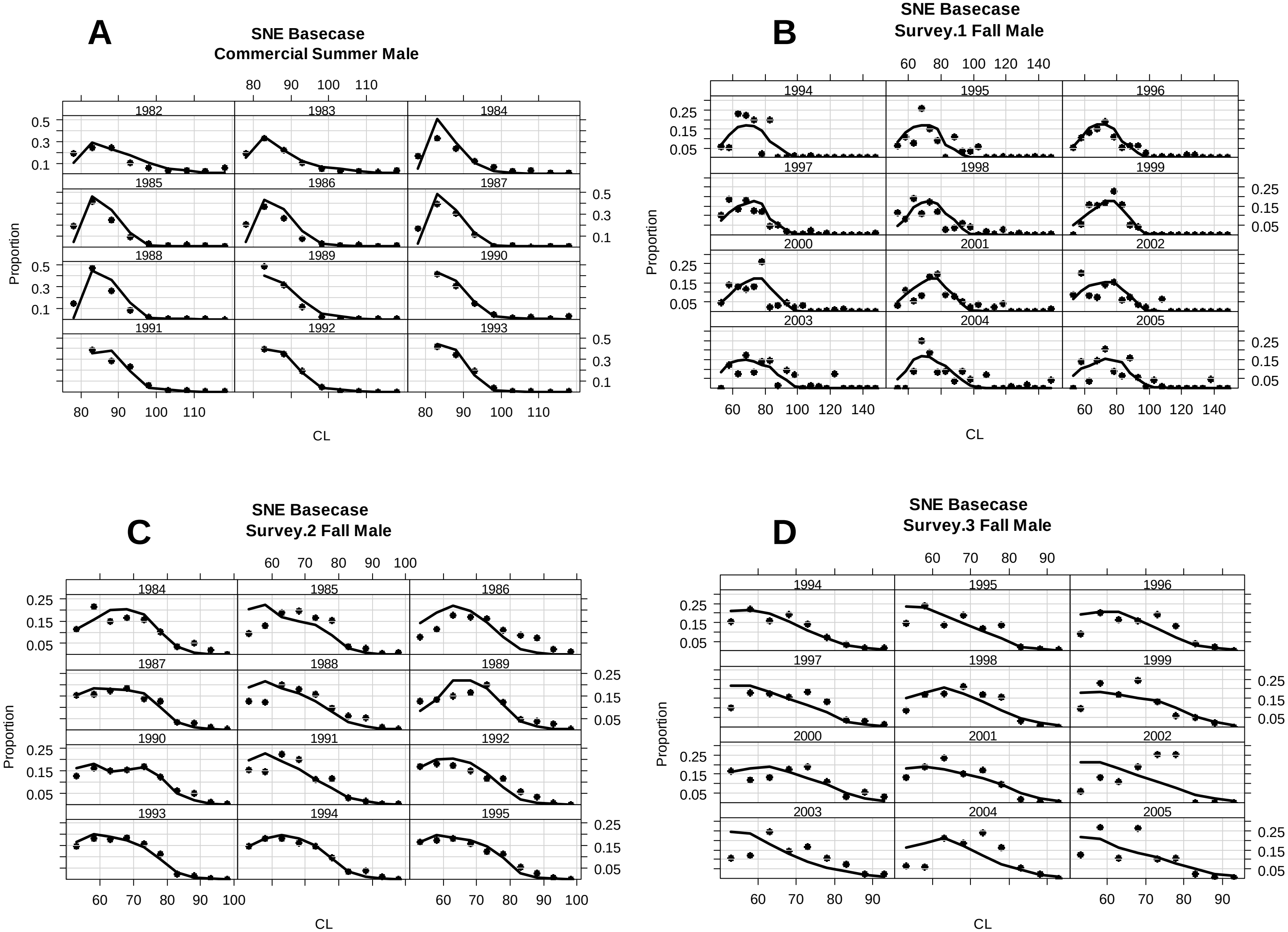
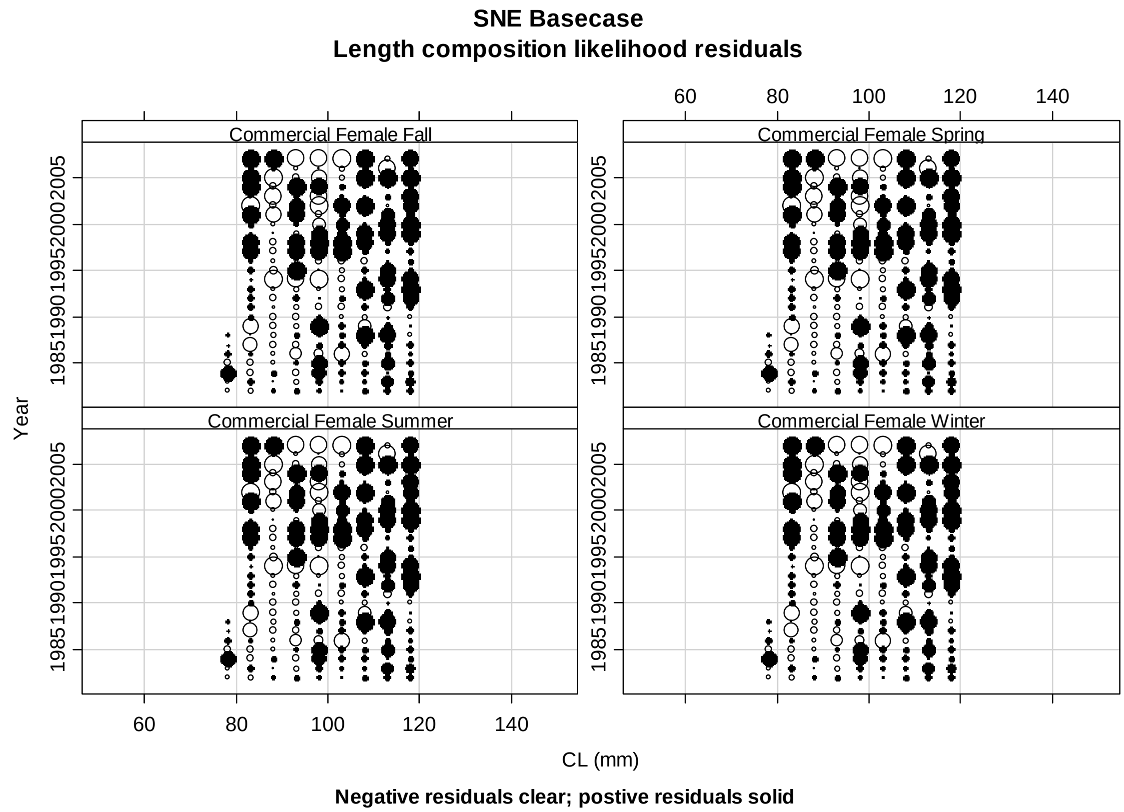


Figure 7.2.3.7. Likelihood residuals for commercial length data in the SNE basecase model.



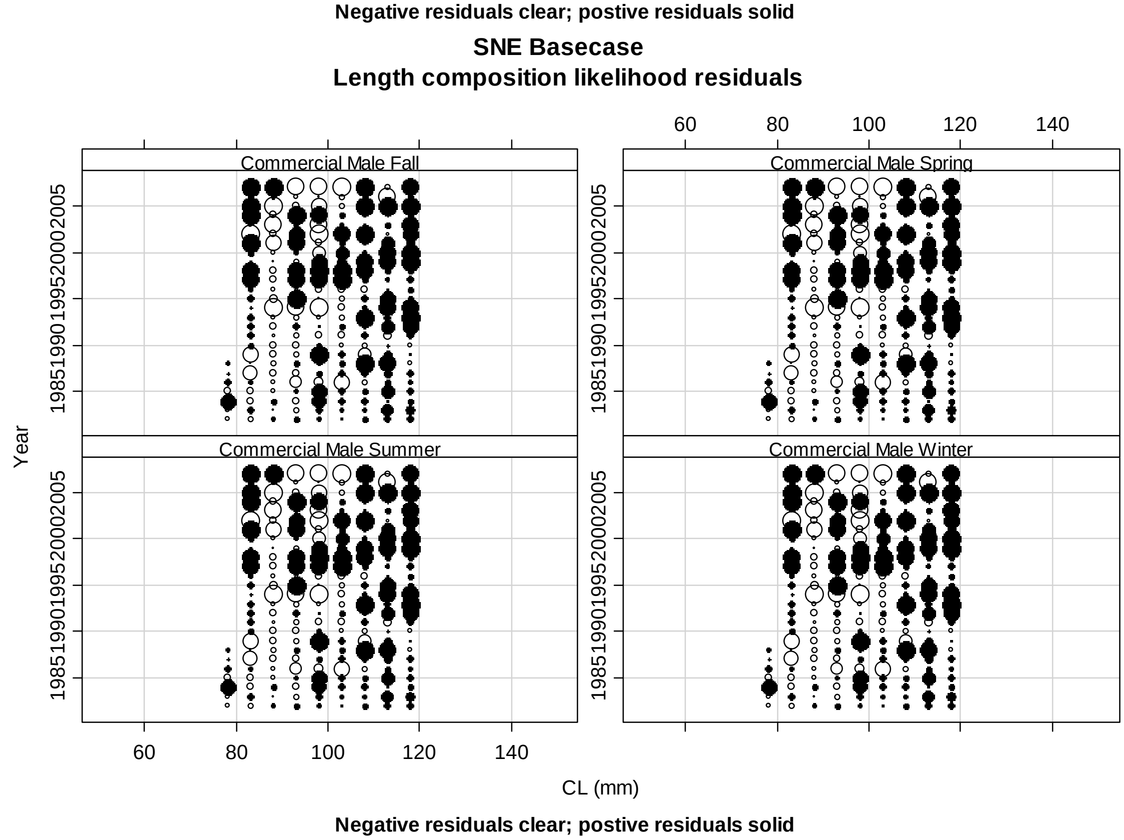
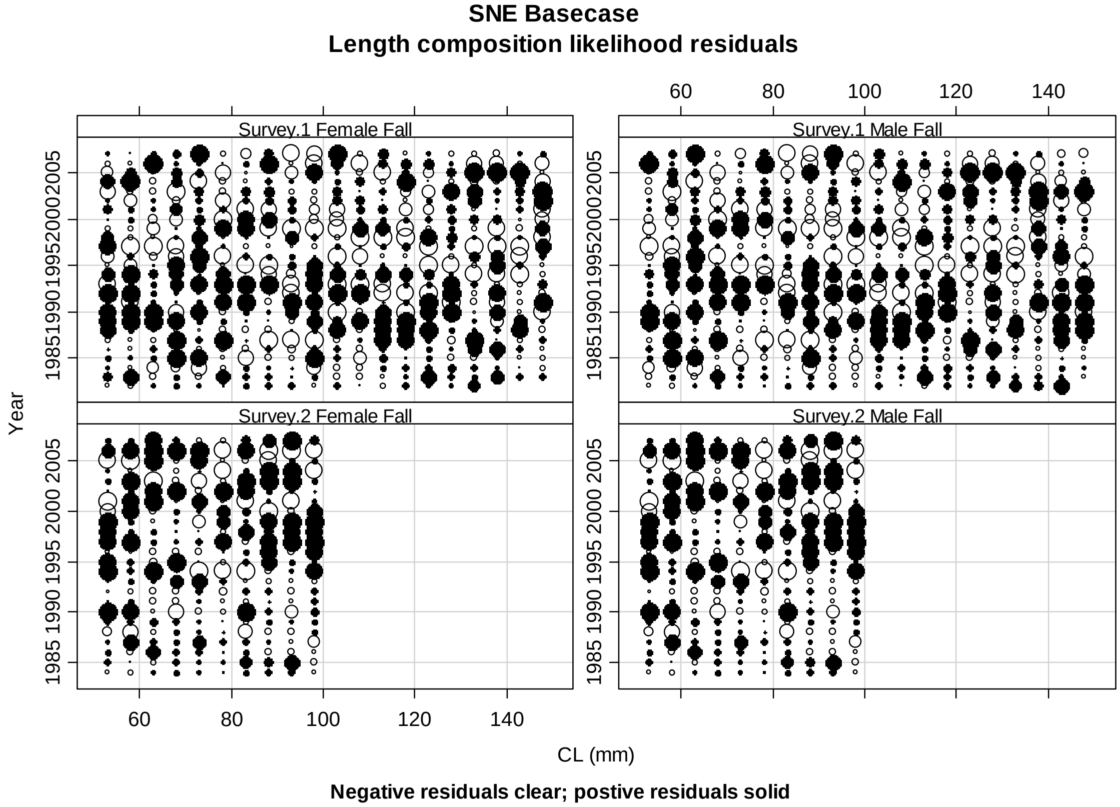


Figure 7.2.3.8. Likelihood residuals for survey length data in the SNE basecase model.



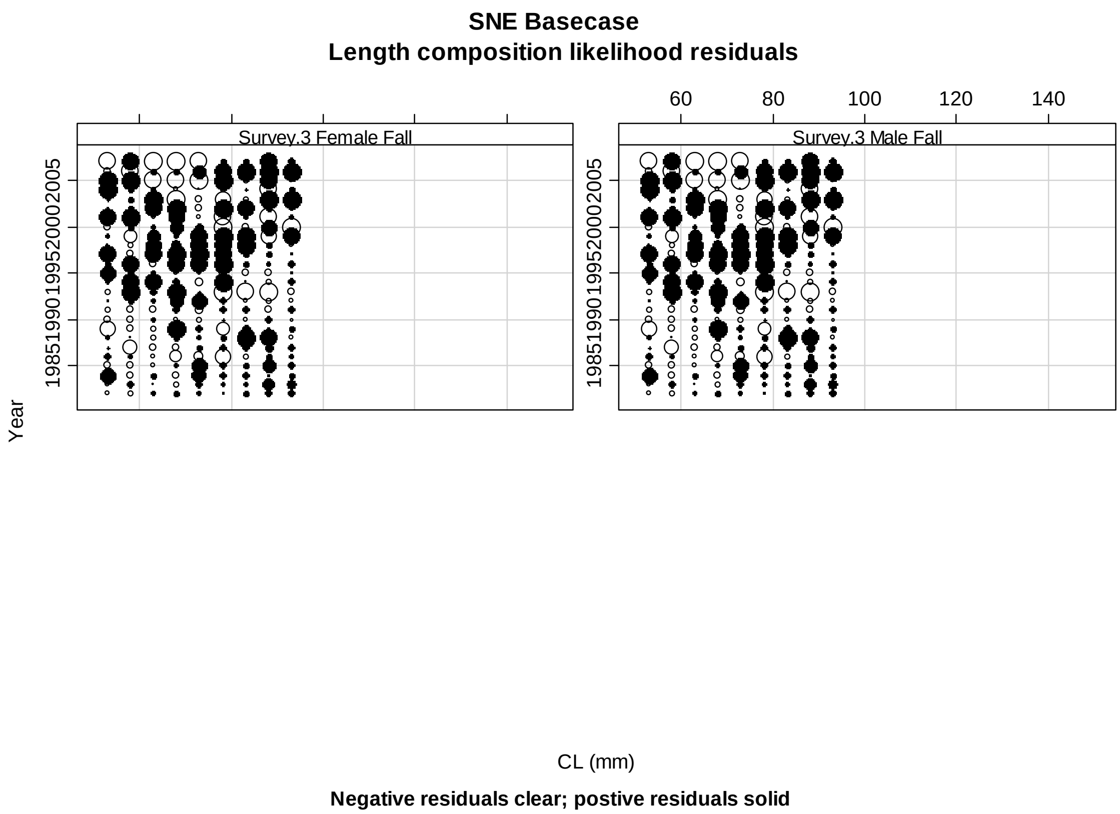
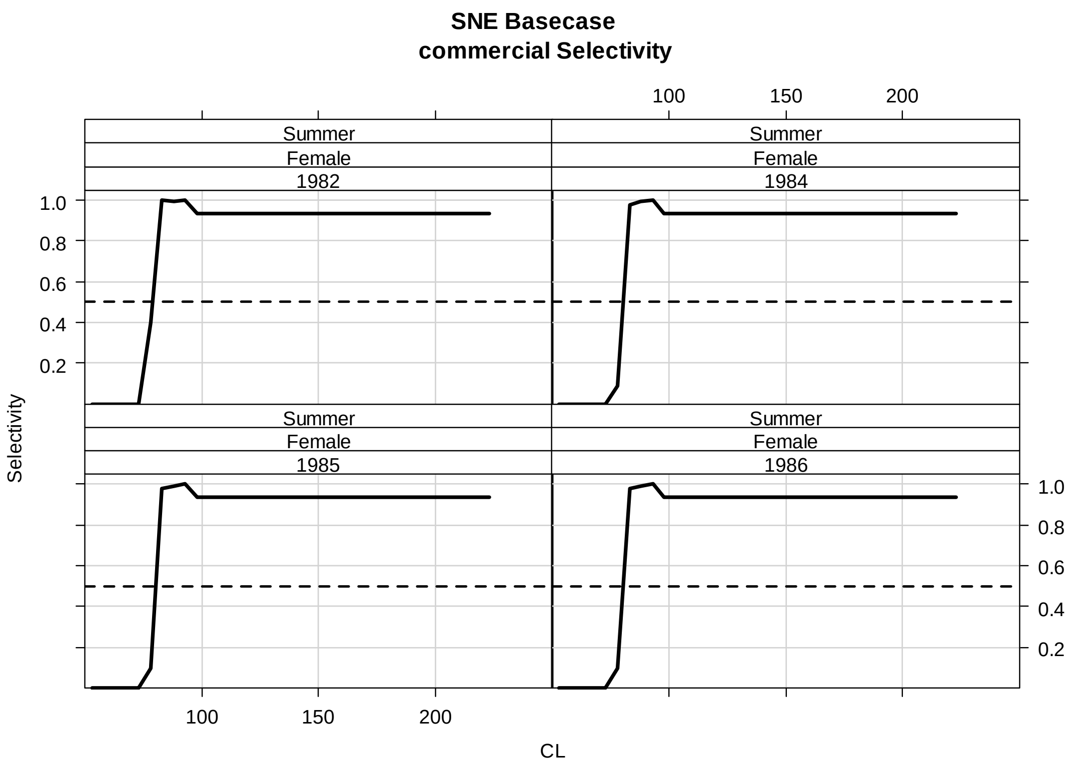


Figure 7.2.3.9. Example annual specified commercial selectivity curves for females (above) and males (below) in the basecase model for SNE.



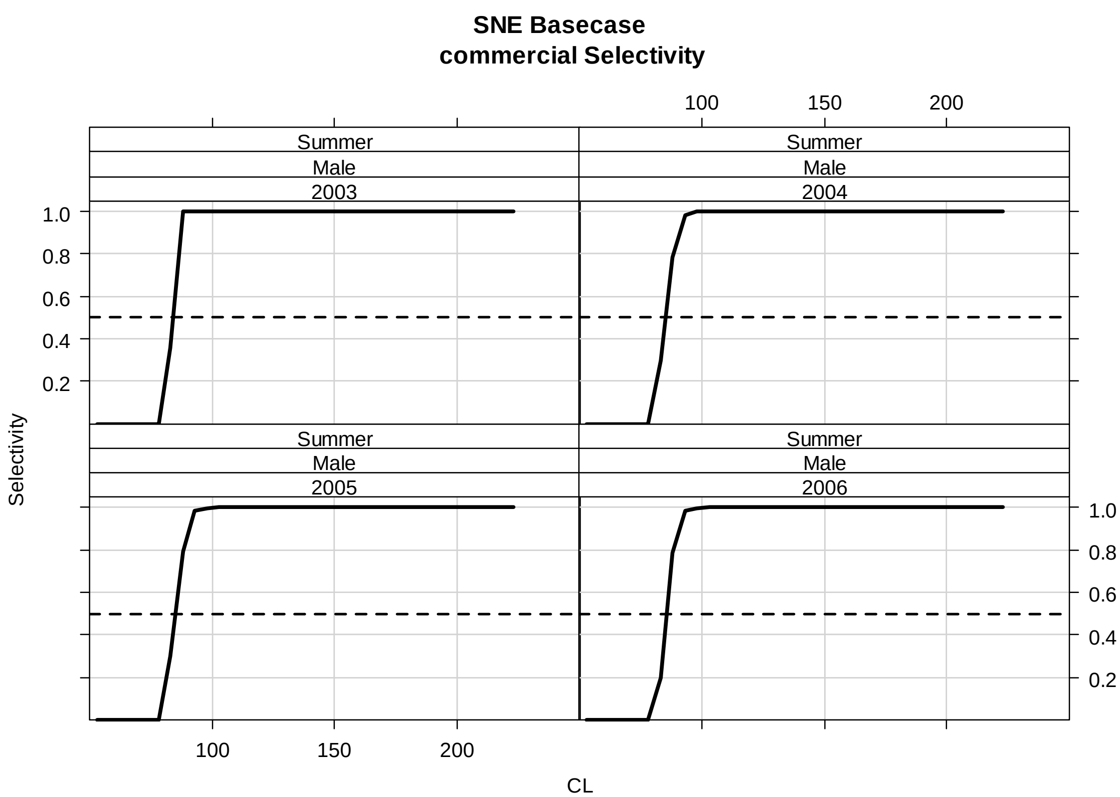


Figure 7.2.3.10. Maturity at length for female (above) and male (below) lobster in the SNE basecase model.

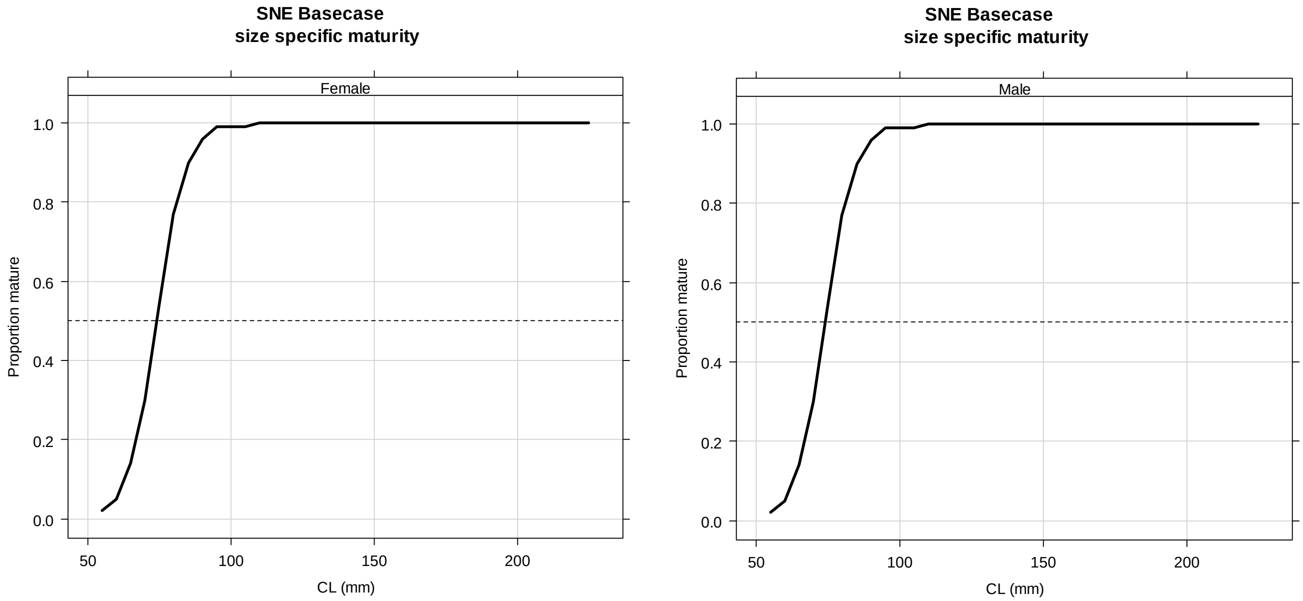


Figure 7.2.3.11. Survey selectivity curves for NEFSC fall bottom trawl (Survey 1), CT DEP (Survey 2), and RI DEM (Survey 3) estimated in the SNE basecase model.

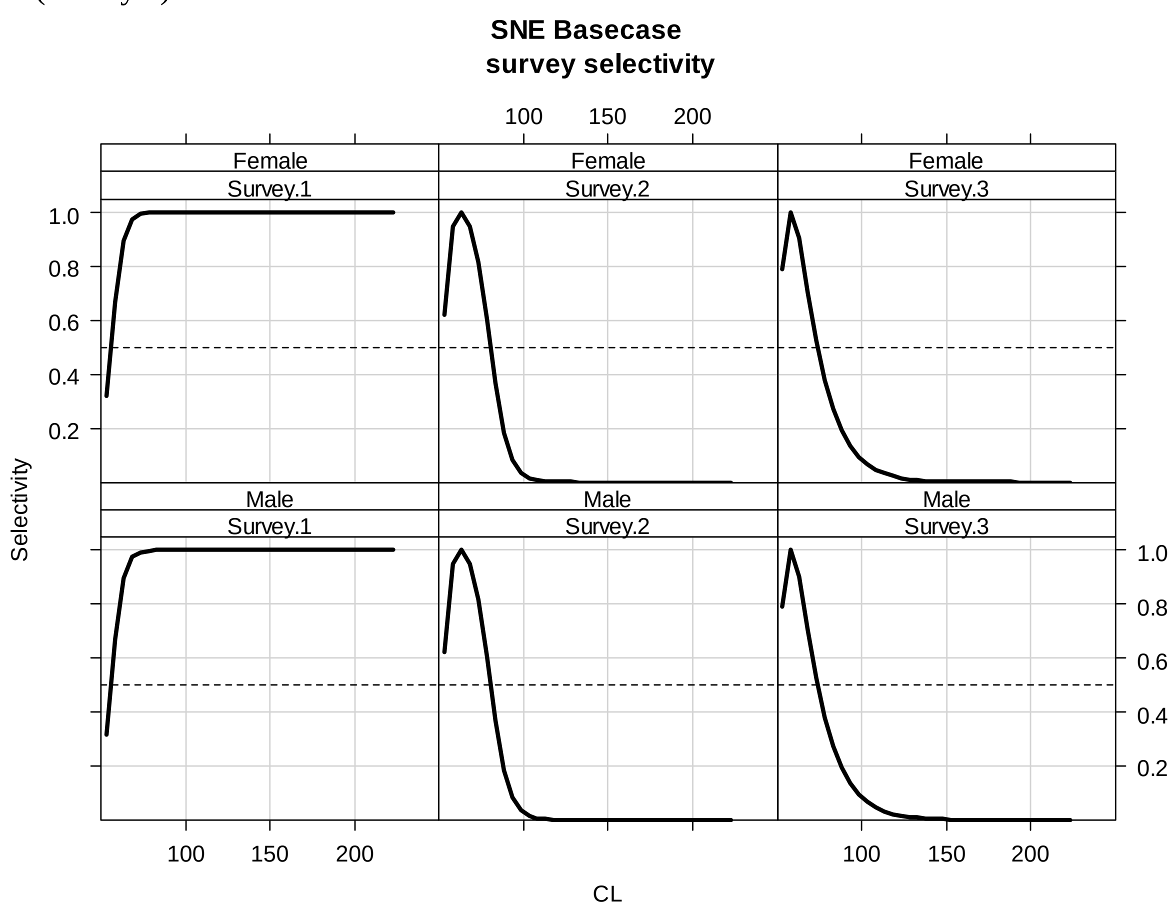


Figure 7.2.3.12. Annual effective exploitation rate (top left), reference abundance (top right), and female spawning biomass (bottom) with associated trend based reference point (median 1984-2003) and status measure (mean 2005-2007) from the basecase model for SNE.

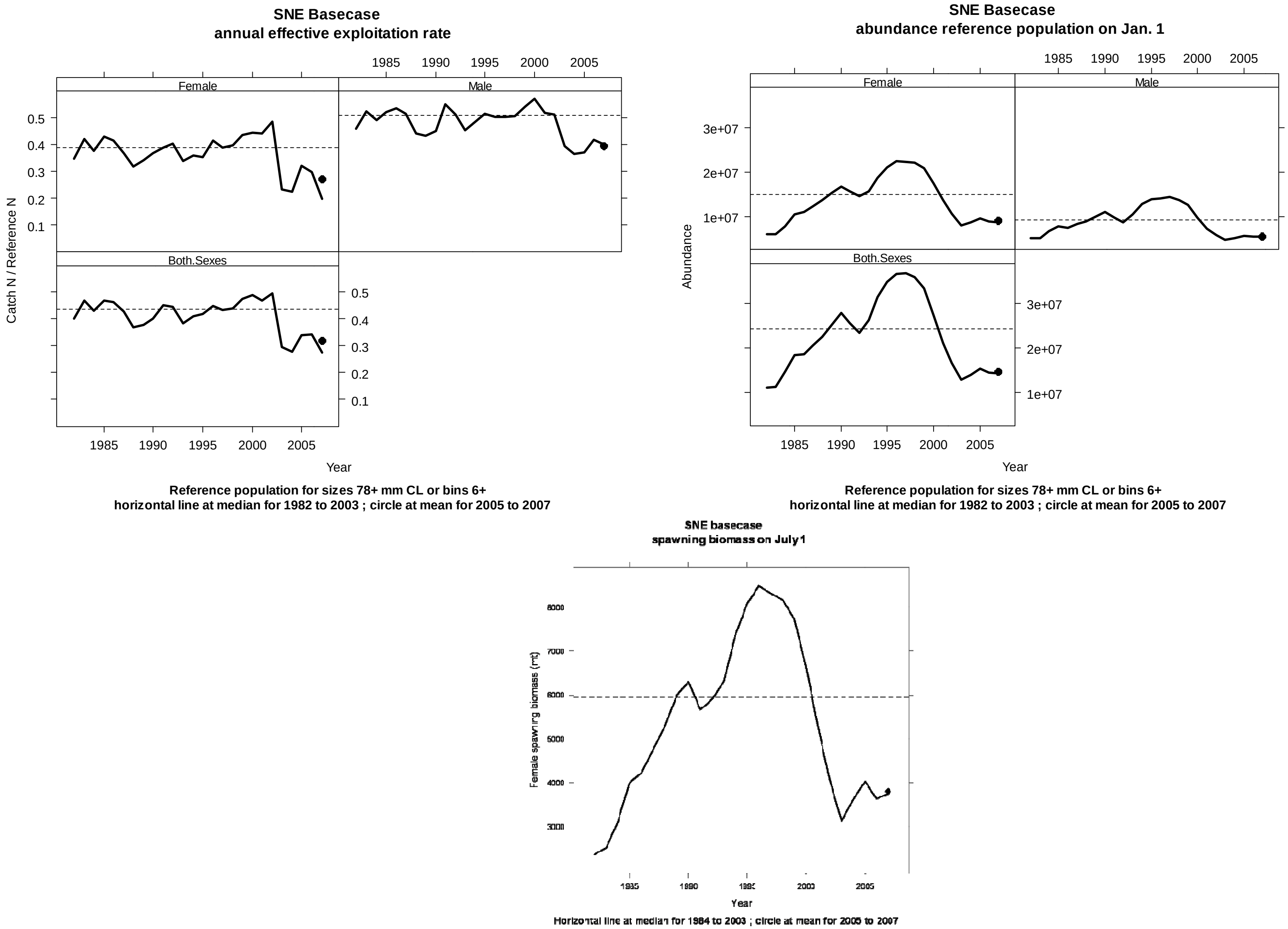


Figure 7.2.3.13. Recruitment estimates from the basecase model for SNE.

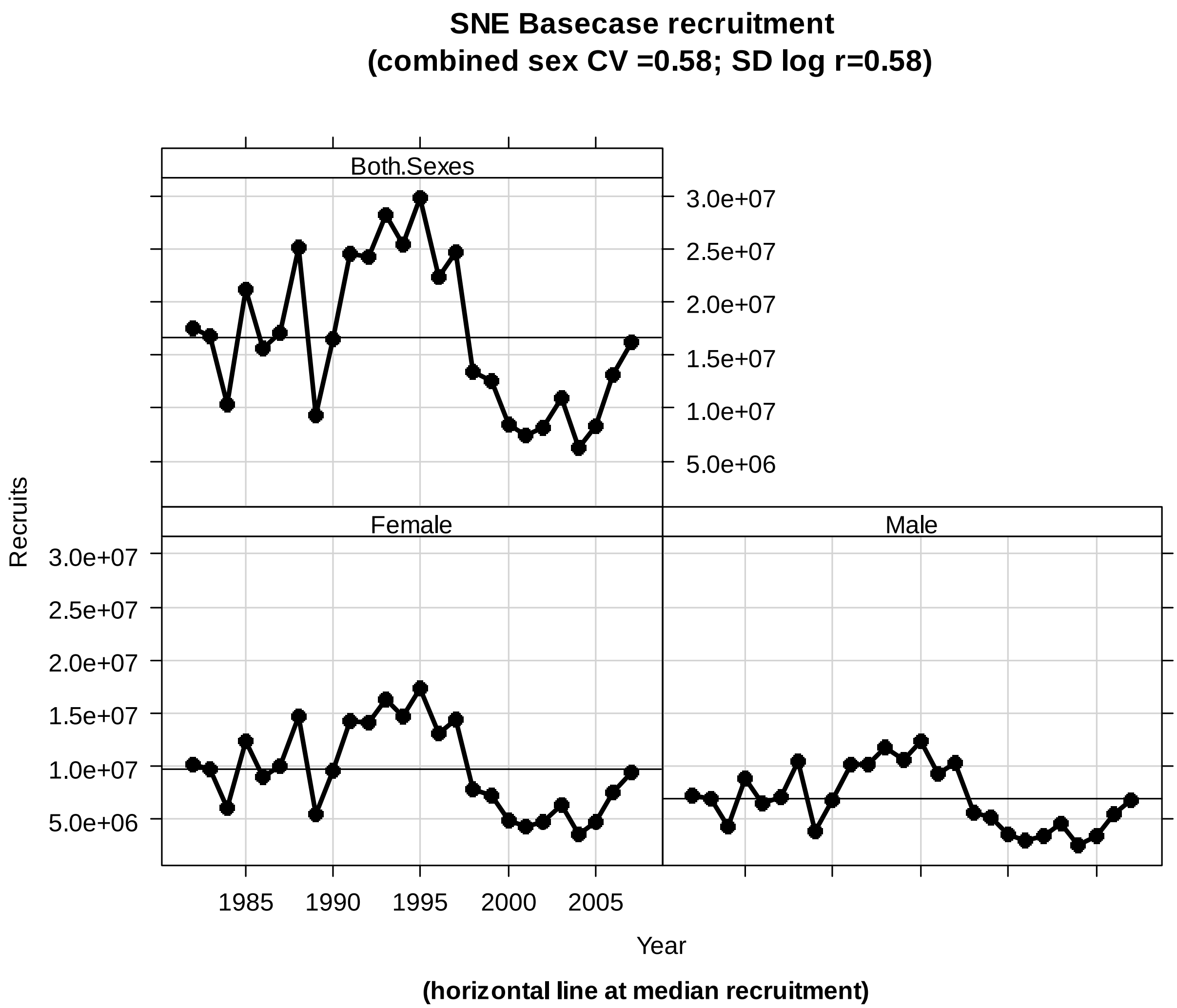


Figure 7.4.1.1. CSM retrospective analysis for GOM MA DMF survey.

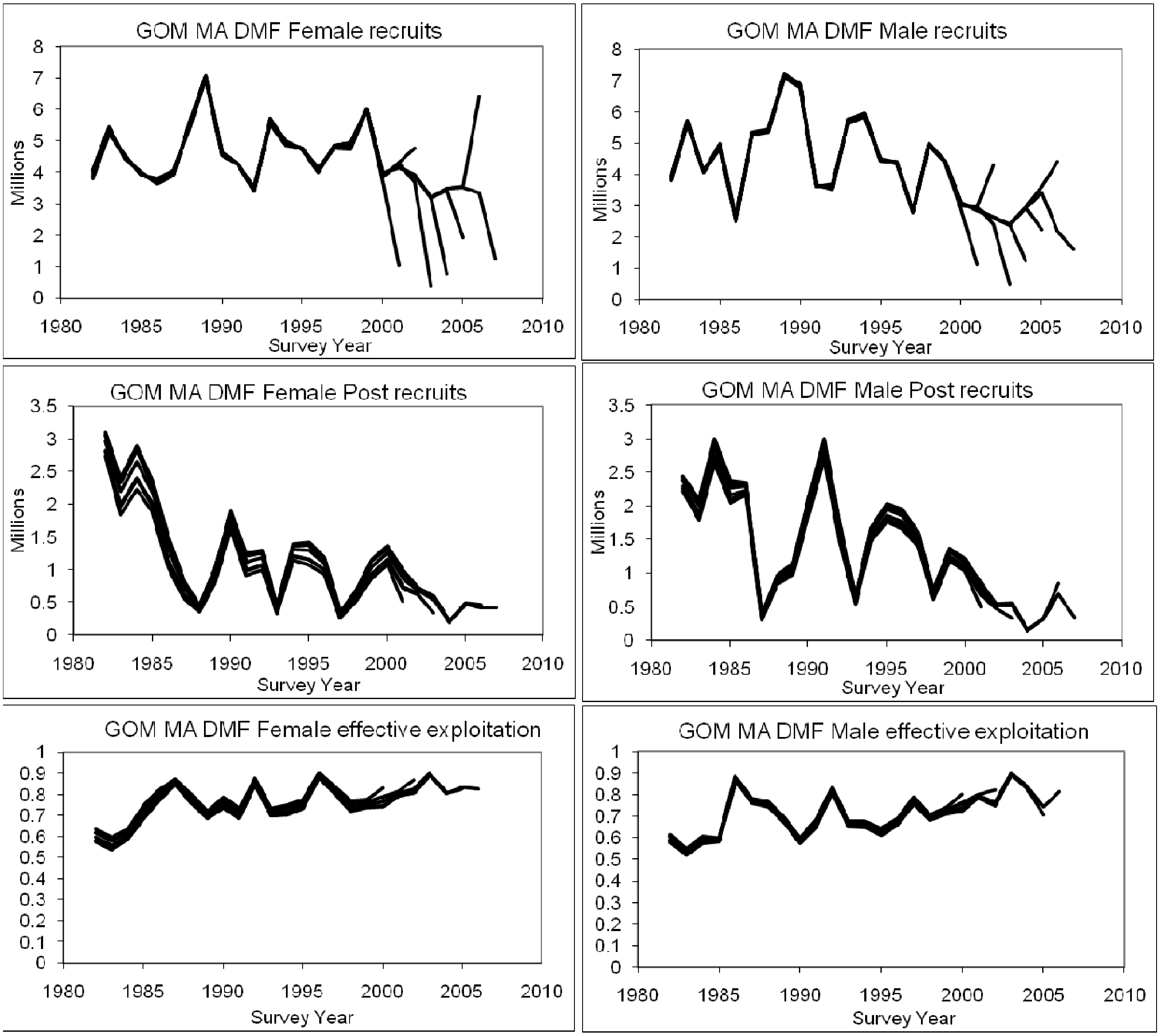


Figure 7.4.1.2. CSM retrospective analysis for GOM NEFSC survey.

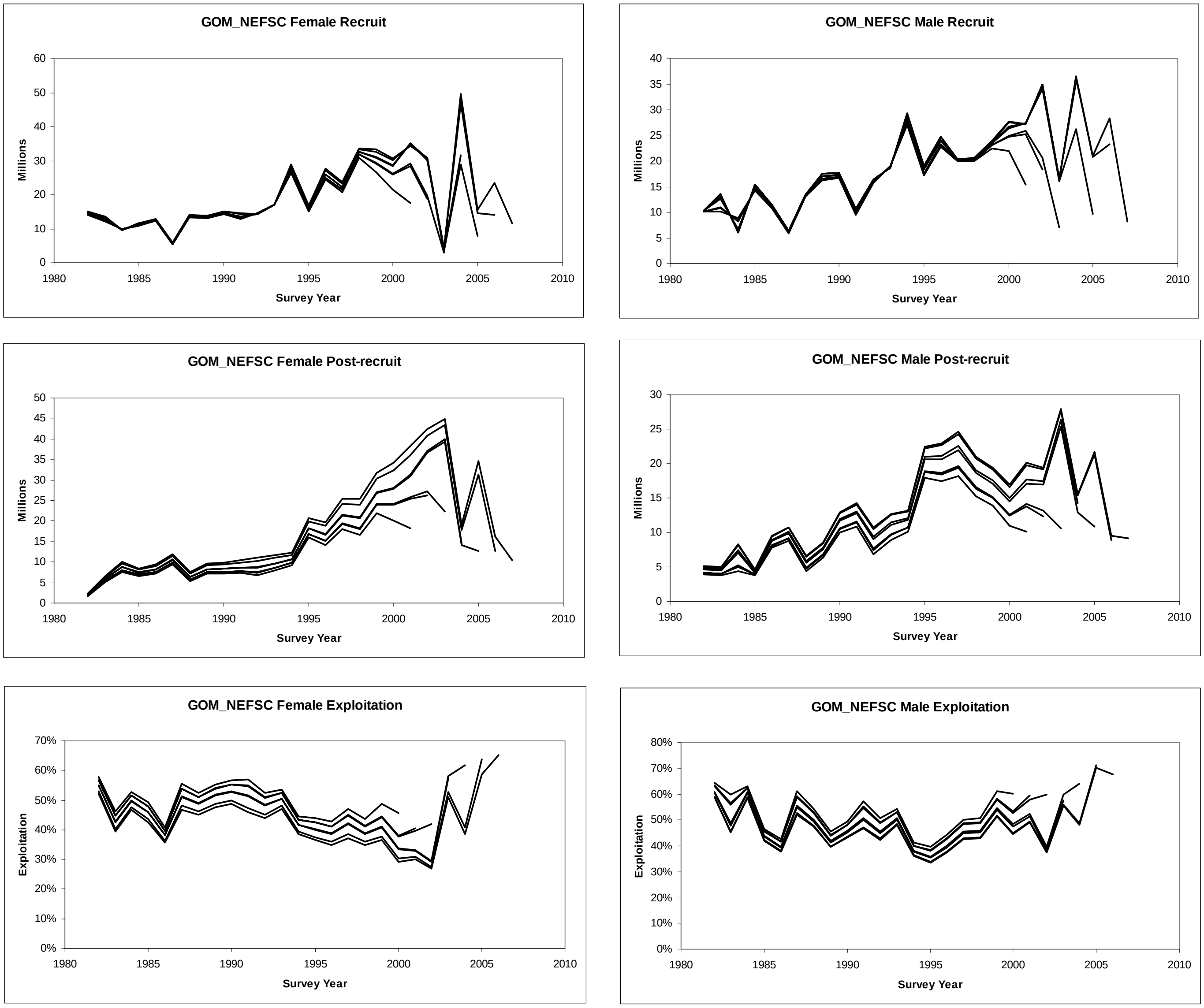


Figure 7.4.1.3. CSM retrospective analysis for GBK NEFSC survey.

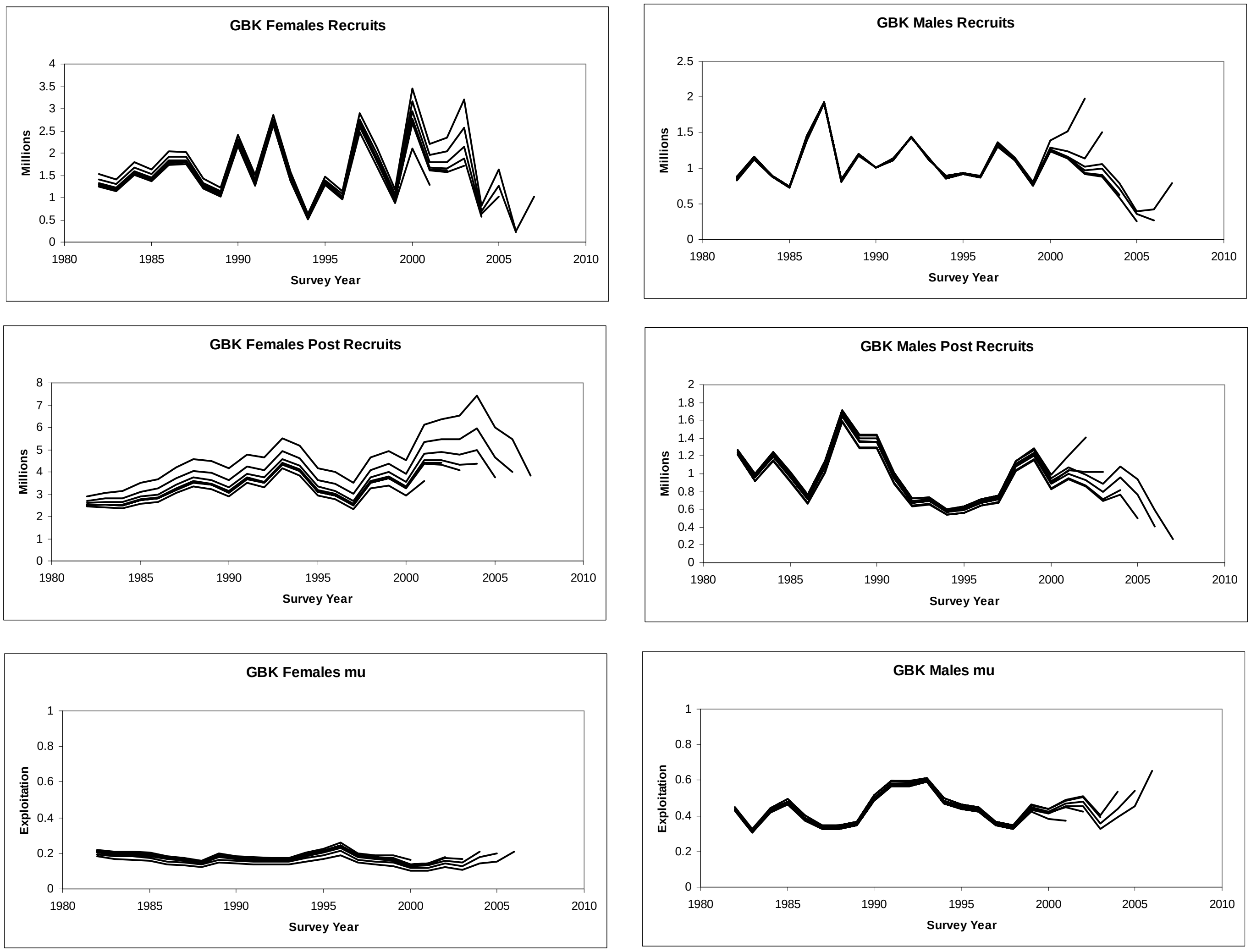


Figure 7.4.1.4. CSM retrospective analysis for SNE CT DEP survey.

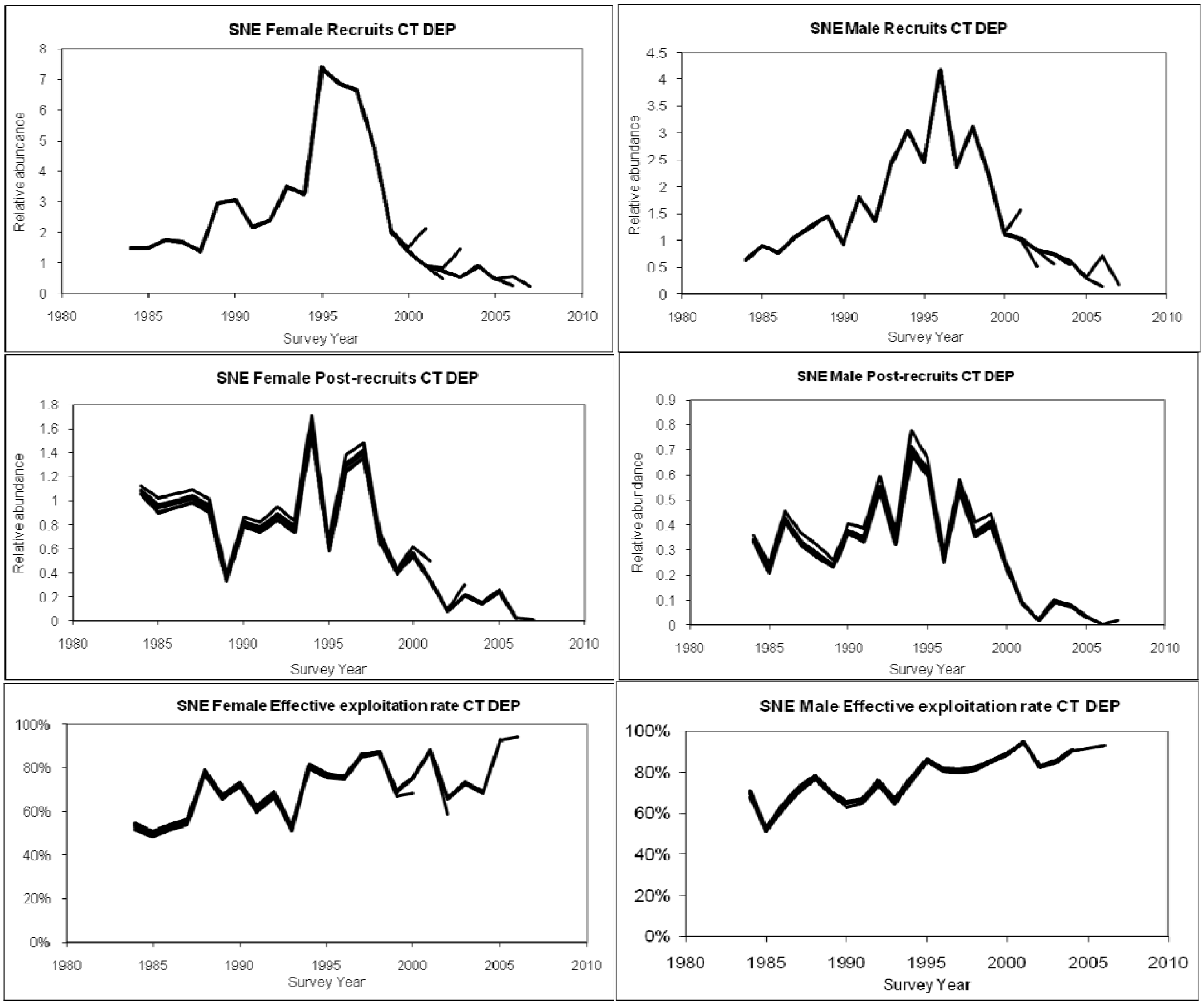


Figure 7.4.1.5. CSM retrospective analysis for SNE RI DEM survey.

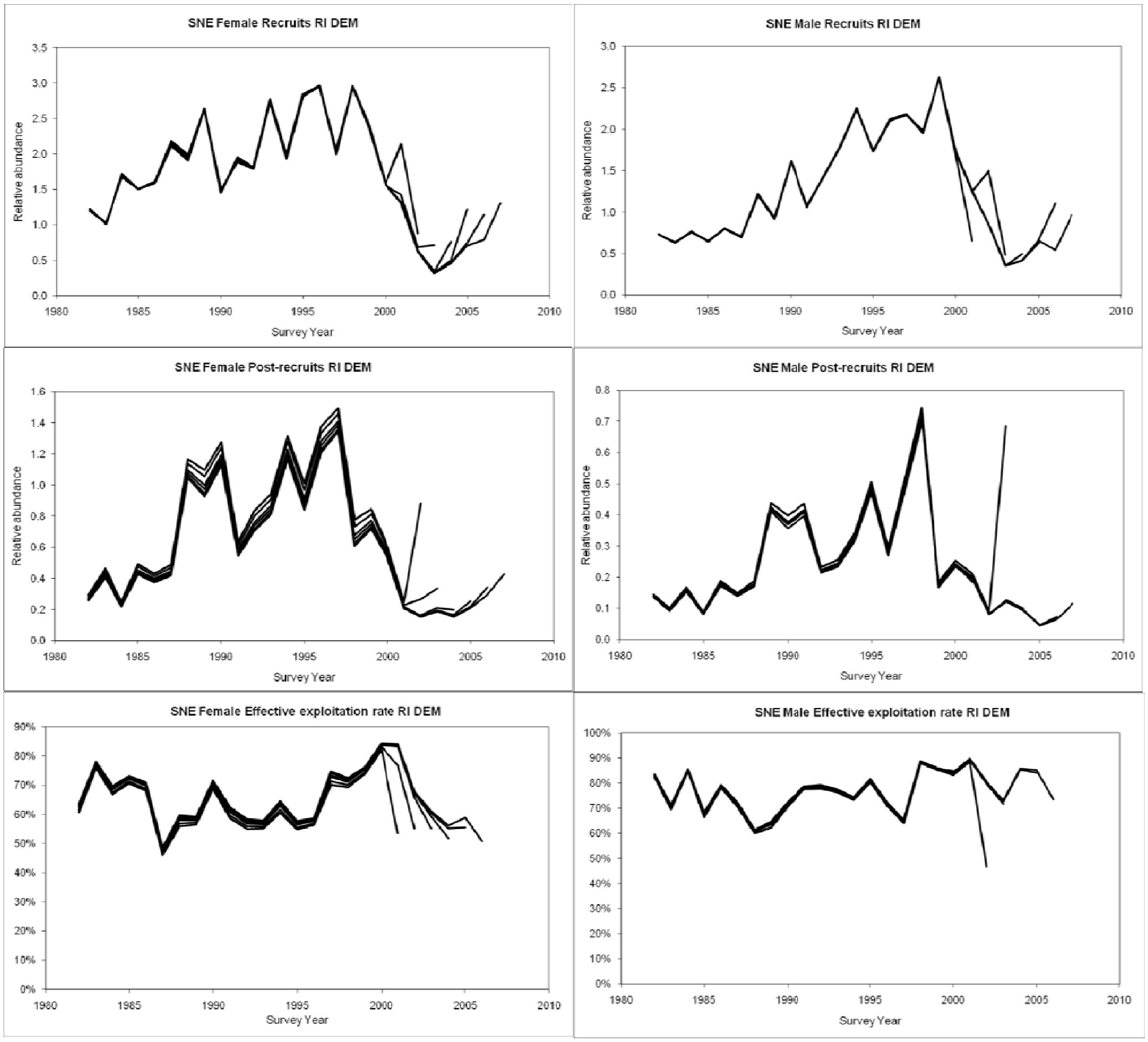


Figure 7.4.1.6. CSM retrospective analysis for SNE NEFSC survey.

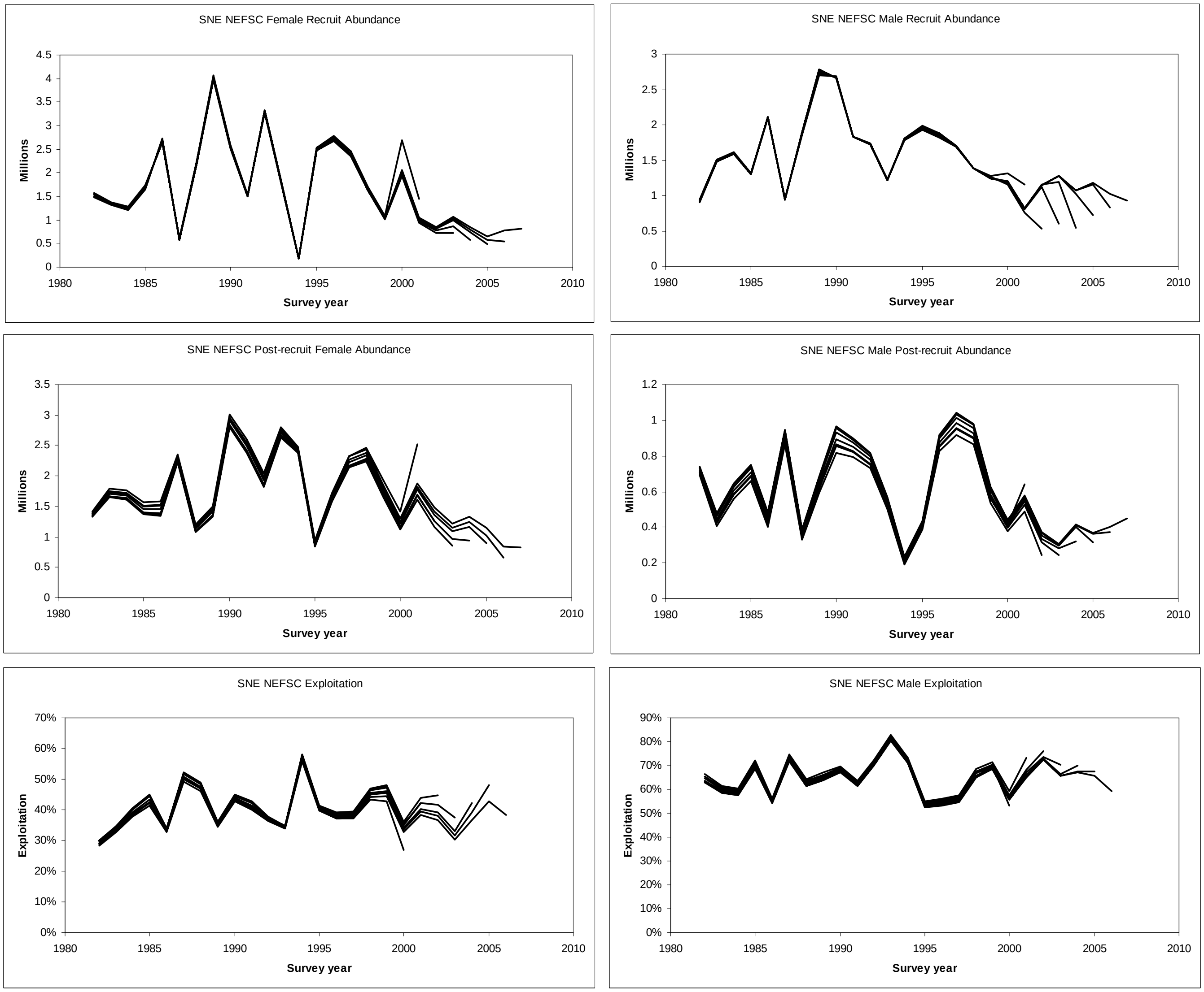


Figure 7.4.2.1. Retrospective analyses for effective exploitation rates (top) and reference abundance (bottom) in the basecase model for GOM.

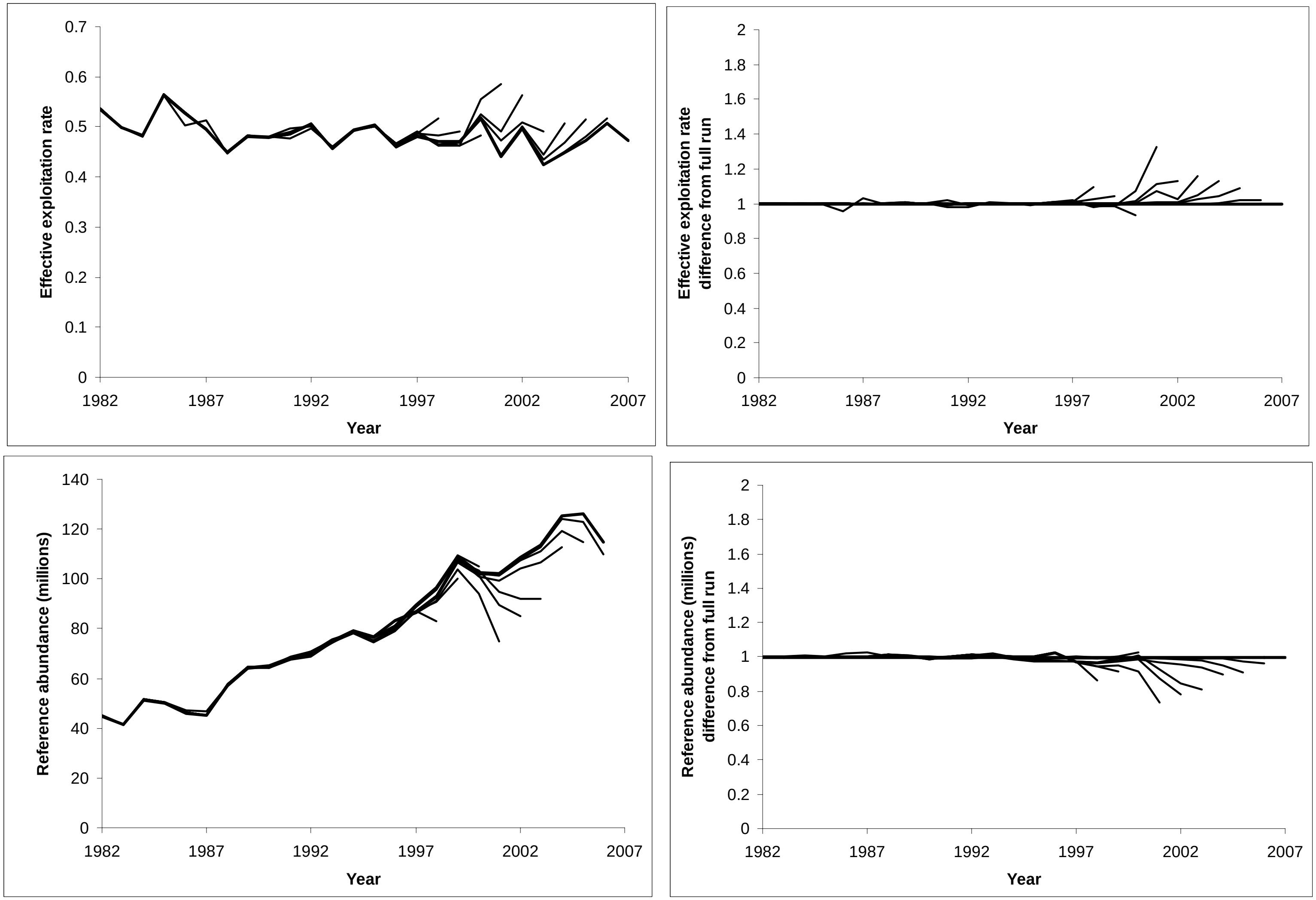


Figure 7.4.2.2 Retrospective analyses for effective exploitation rates (top) and reference abundance (bottom) in the basecase model for GBK.

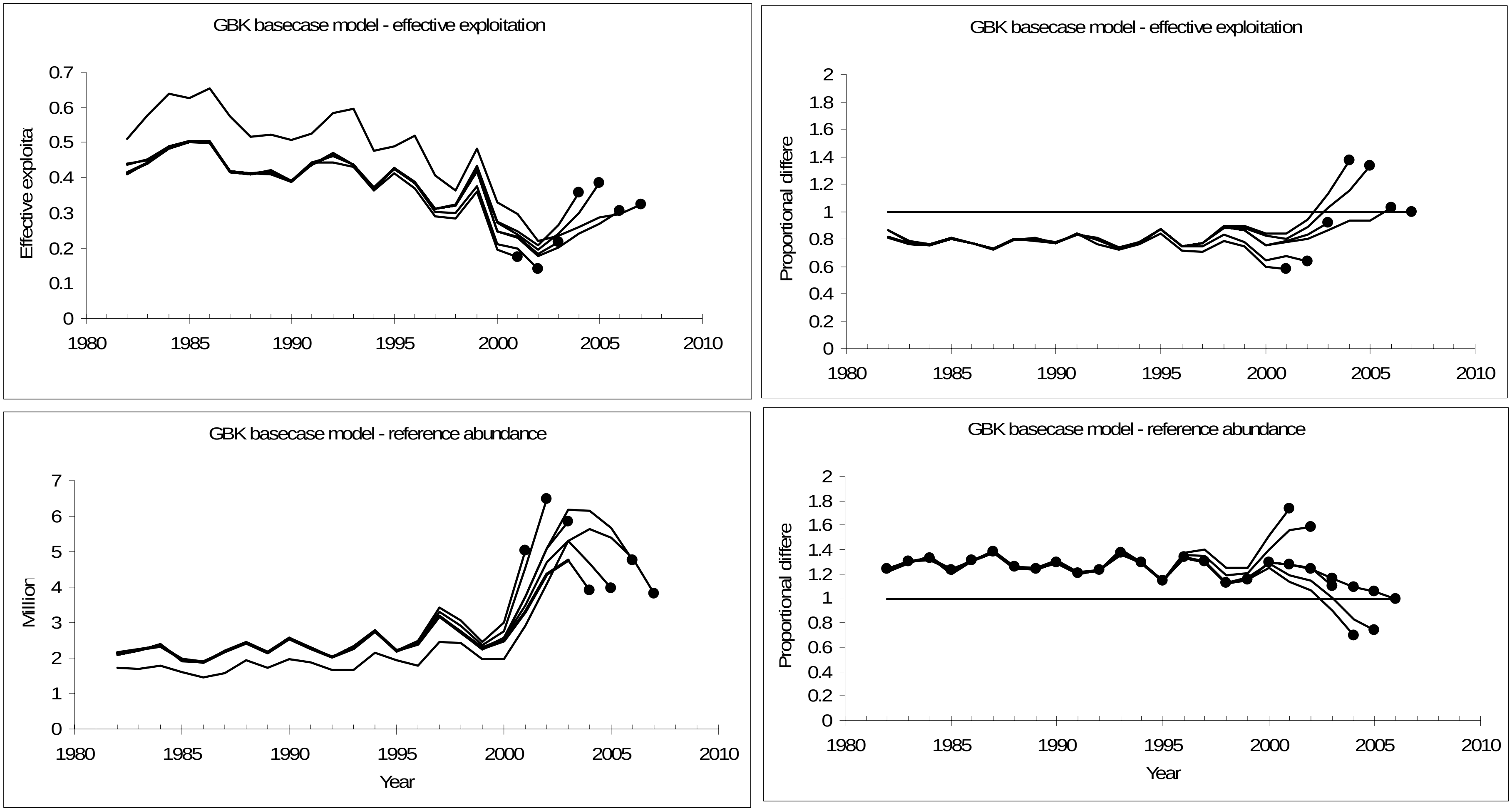


Figure 7.4.2.3 Retrospective analyses for effective exploitation rates (top) and reference abundance (bottom) in the alternate "fit spring" run for GBK.

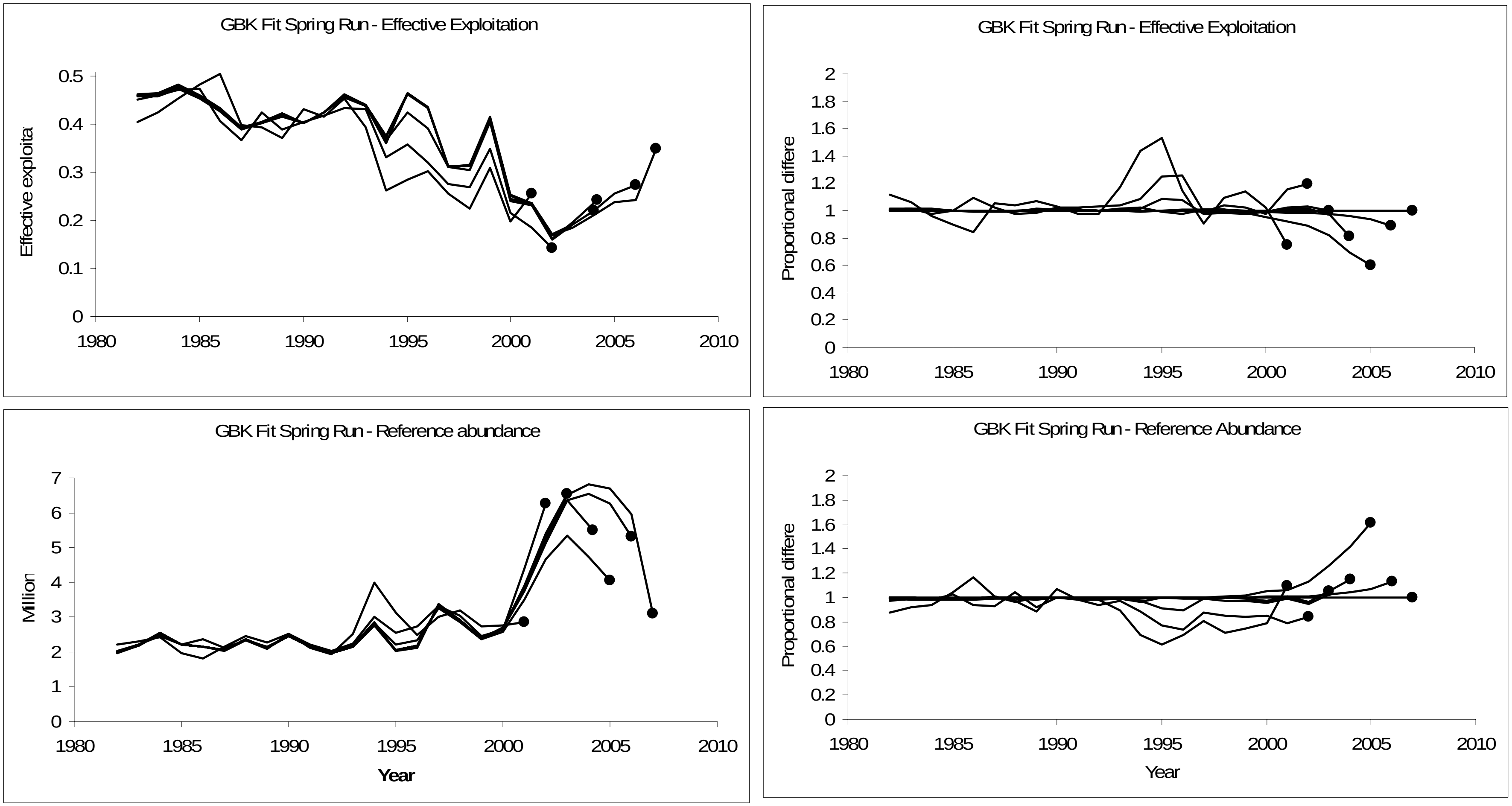


Figure 7.4.2.4 Retrospective analyses for effective exploitation rates (top) and reference abundance (bottom) in the basecase model for SNE.

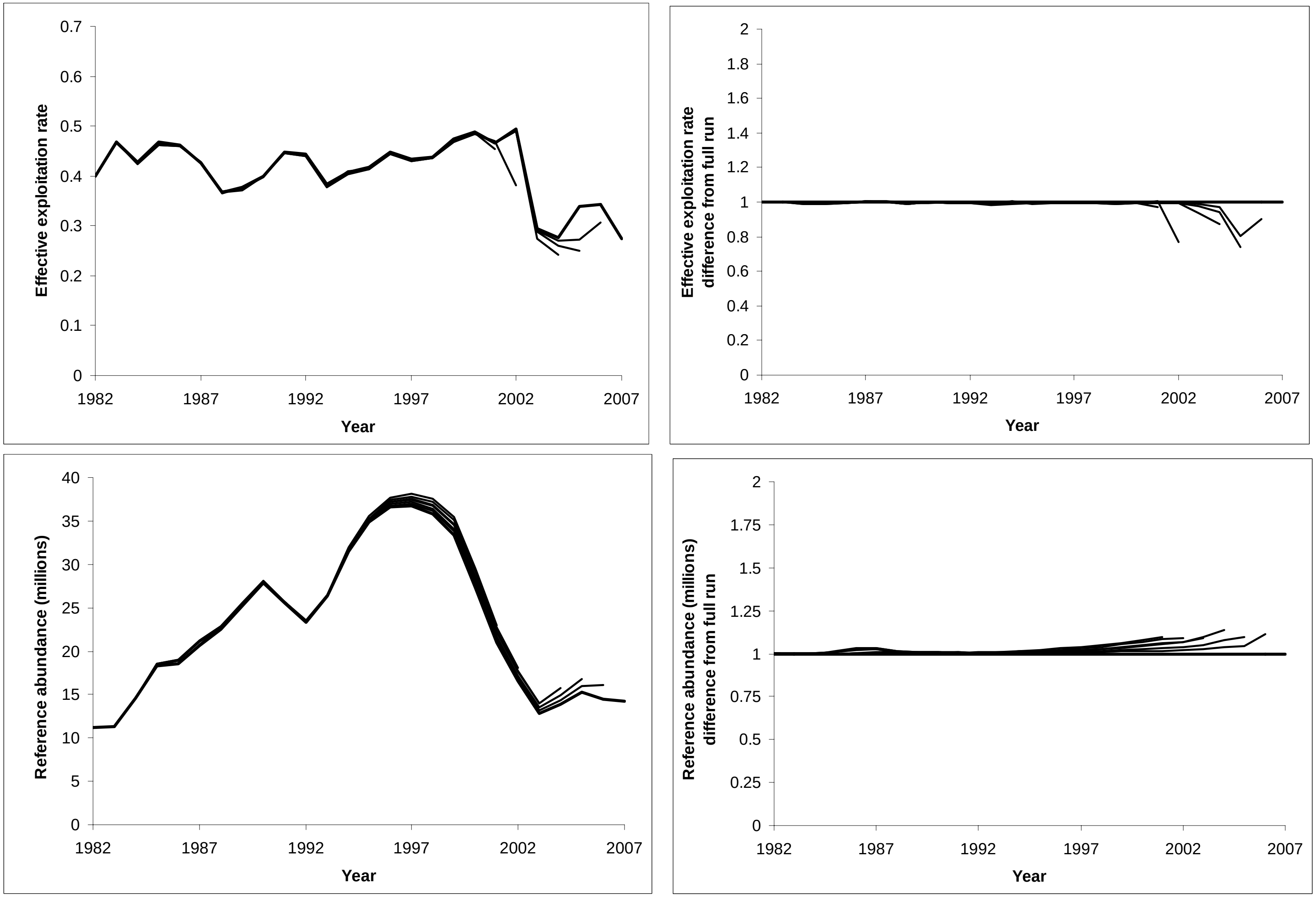


Figure 8.1.1. Trends in fishing mortality and abundance predicted by the CSM model. Solid lines indicate targets and dashed lines indicate thresholds.

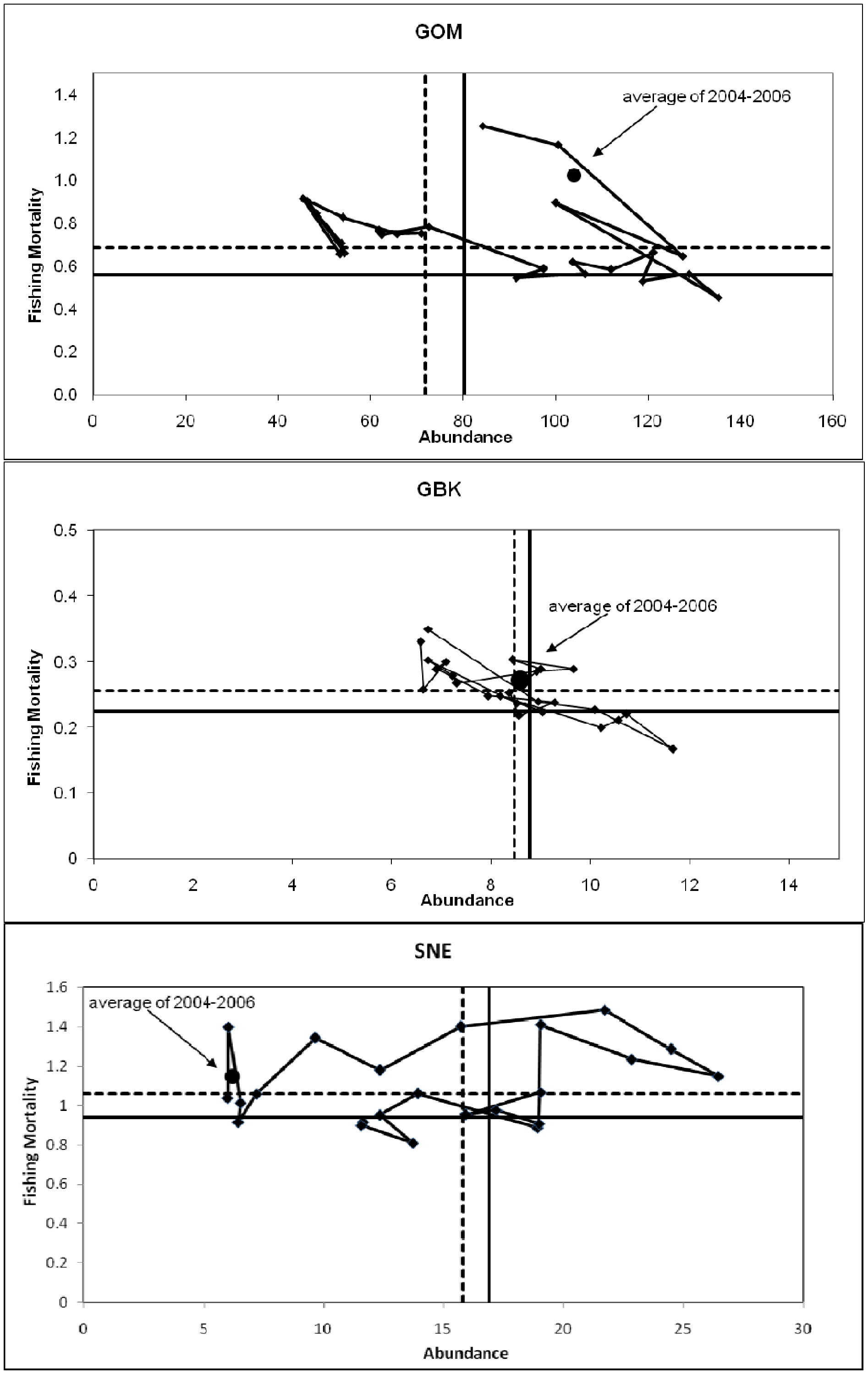
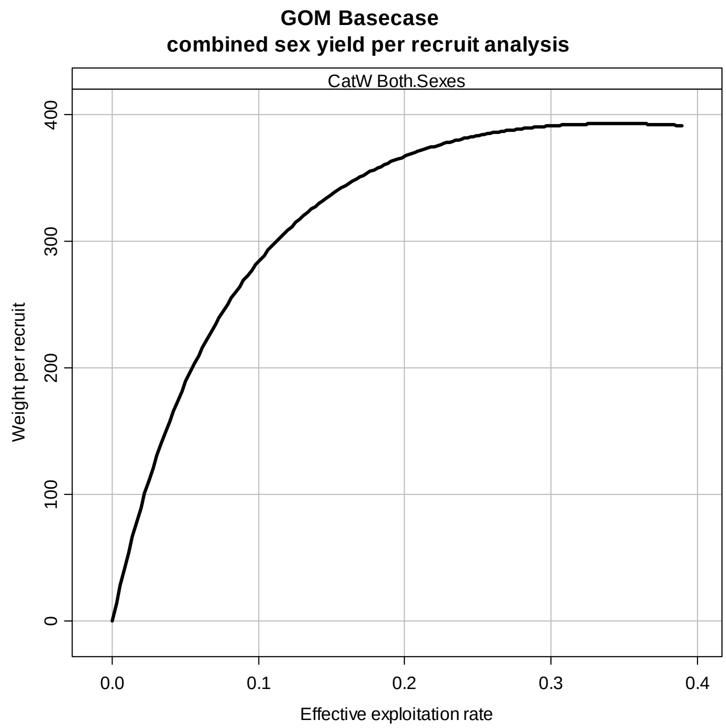


Figure 8.2.1.1. Yield per recruit curve for both sexes (above) and female spawning stock biomass per recruit (below) from the basecase model for GOM.



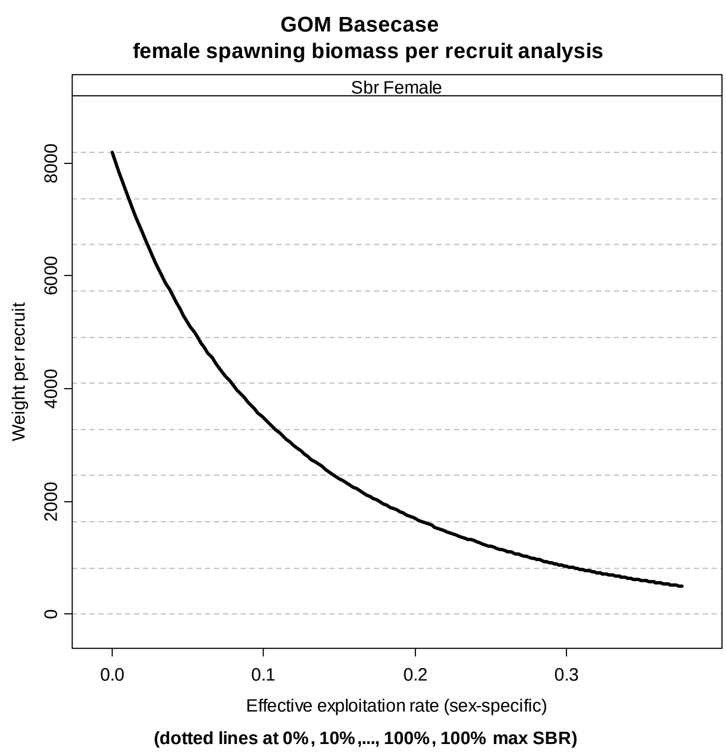


Figure 8.2.2.1. Yield per recruit curve for both sexes (above) and spawning biomass per recruit curve for female lobster from the basecase model for GBK.

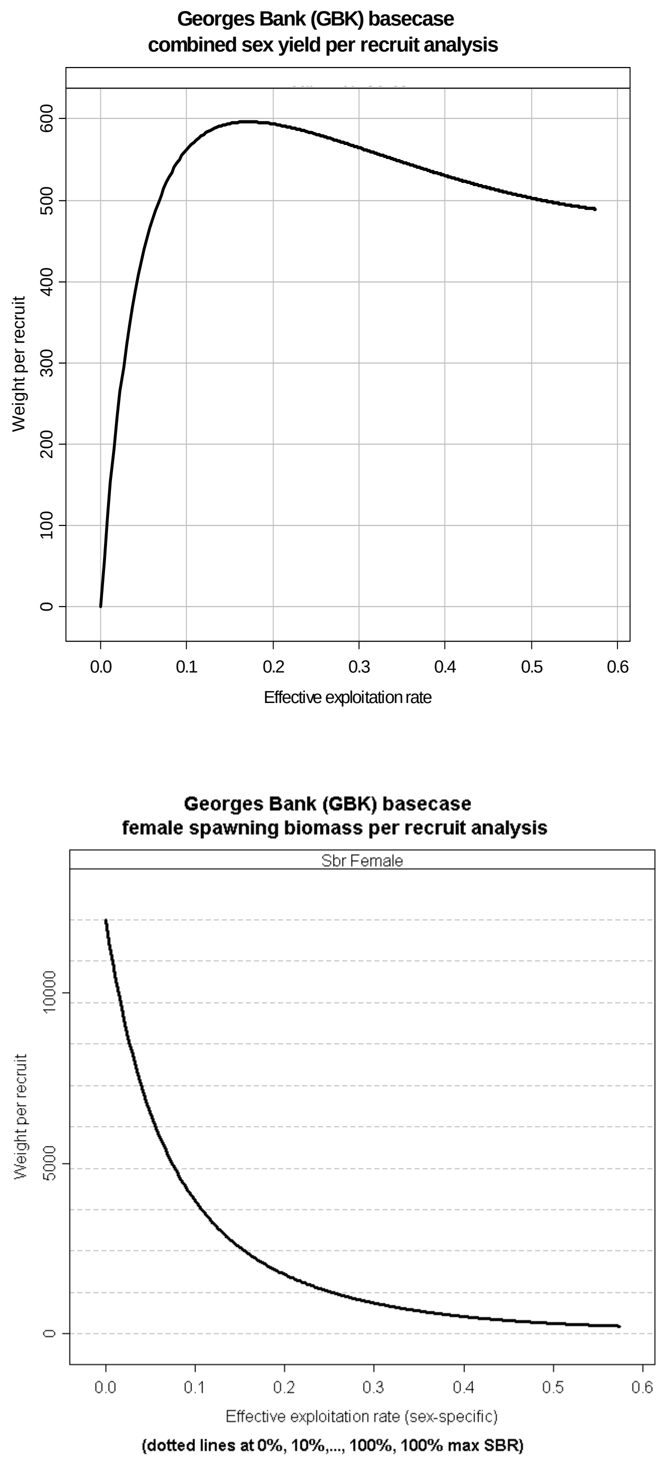
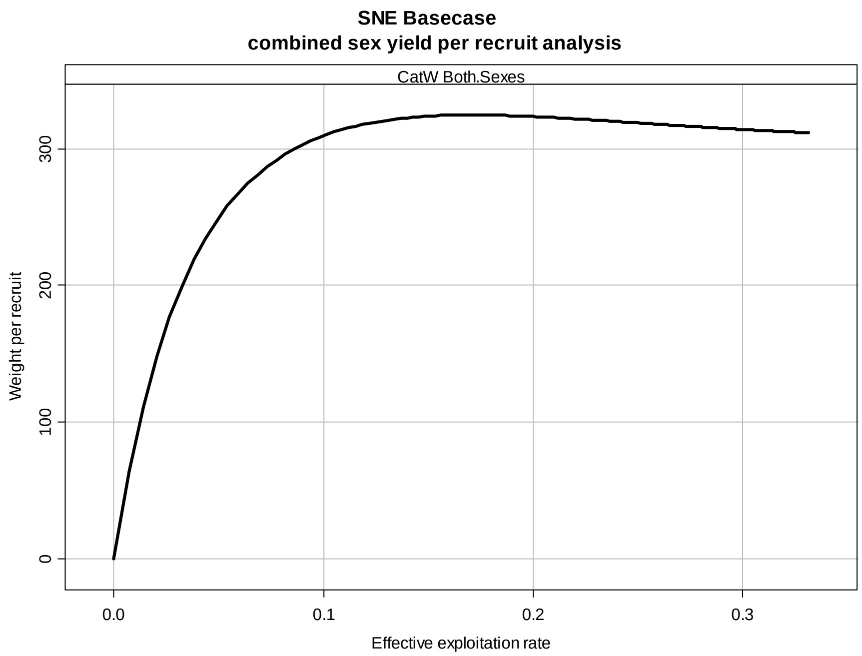


Figure 8.2.3.1. Yield per recruit curve for both sexes (above) and spawning biomass per recruit curve for female lobster (below) from the basecase model for SNE.



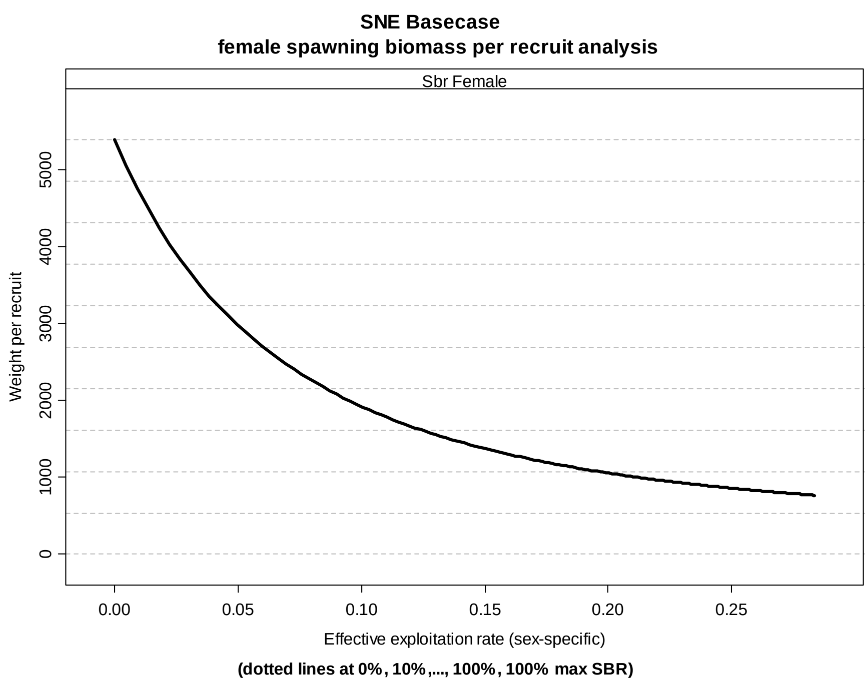
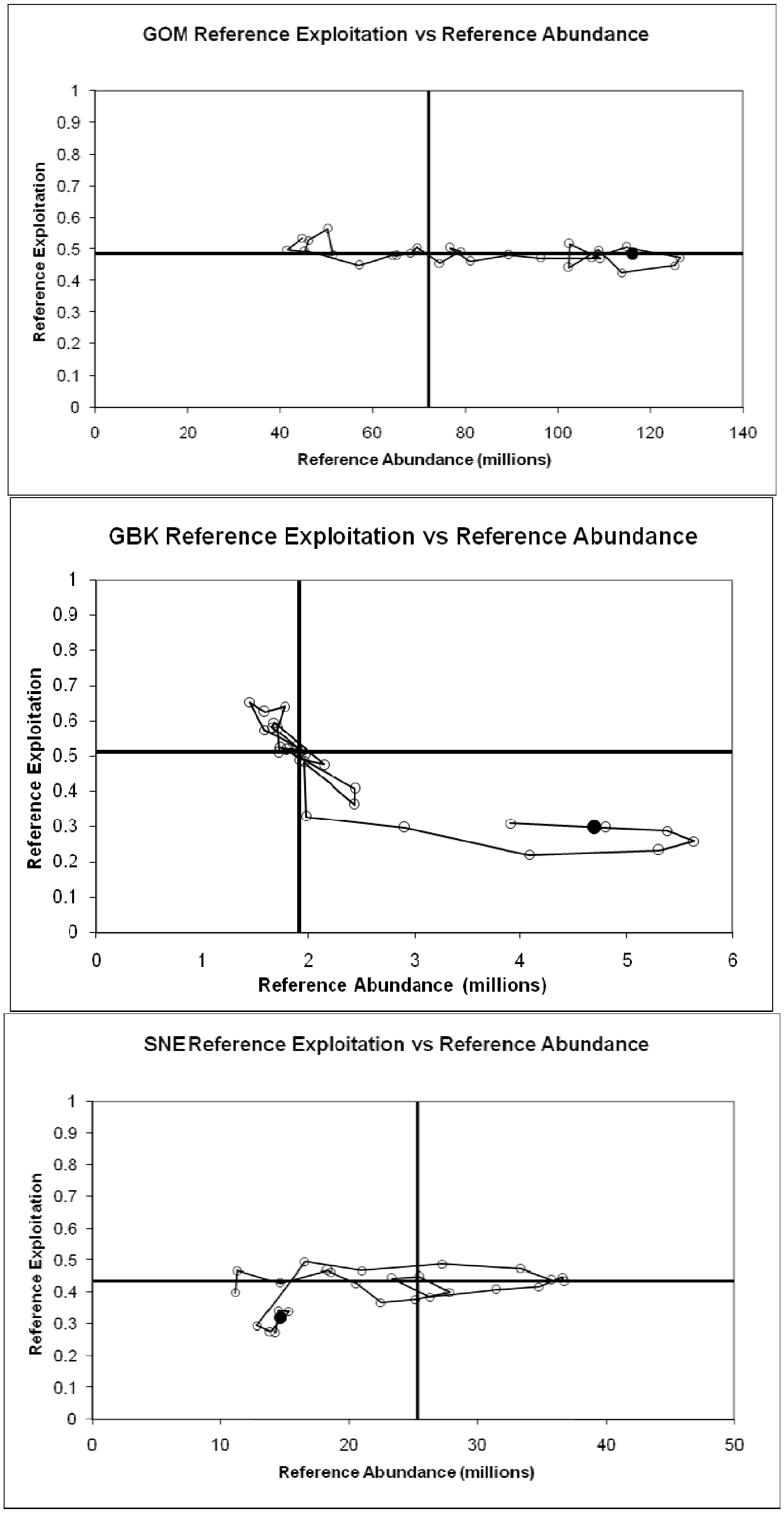


Figure 8.3.1. Quadrant plots of effective exploitation versus reference abundance for GOM (top), GBK (middle), and SNE (bottom). Solid lines denote median thresholds.



Appendix 1. Alternate Landings for Maine

Background to be reviewed

Until 2004, the reported Maine landings were tallied on a voluntary basis by lobster dealers. Since 2004, dealers are required to report annually with a monthly breakdown. In 1967 the Maine DMR initiated a coast wide port sampling survey of the Maine lobster fishery. This program was designed to track temporal changes in catch and effort in Maine, and has remained remarkably consistent in data collection protocols. A statistic of the port sampling program calculated each month is an expanded estimate of state landings based on sampled landings, the number of dealers buying from a minimum of five fishermen, and the ratio of potential fishing days in each month to days sampled. These expanded estimates are designed to be an unbiased estimate of landings. The expanded estimate should never exceed the NMFS/DMR reported landings as the port sampling program selects only those dealers buying from more than five vessels.

We assert there are two lines of evidence that suggest that Maine landings were under reported from 1997 to 2003 based on a comparison of the NMFS/DMR reported landings and the expanded estimates generated from the port sampling program. The time series of reported landings (NMFS and DMR) and expanded estimates (DMR port sampling) were significantly correlated from 1967 to 1996 ($r=0.852$, $p= 0.000$), however the two values converged during 1997 to 2003, until mandatory dealer reporting was implemented in 2004. At this time the expanded estimates and reported landings diverged to a similar pre-1997 ratio from 2004 to 2007($r =0.840$, $p= 0.160$; Figure 1). Additionally, the percentage of months where the expanded estimates exceeded the reported landings was 26% from 1997 to 2003, and 9% for all other years (1967 to 1996 and 2004 to 2007; Table 1).

Programs

DMR and NMFS Landings Program

1967-2000: NMFS funded DMR staff to collect landings from dealers based on mandatory reporting requirements for Federal Permits and updated dealer lists. Non-federal dealer reporting was voluntary and landings were aggregated together by port. However, these dealer lists were s not consistently updated and there was little quality control for dealer reports.

2001-2003: DMR coordinated landings with NMFS. Non-federal landings were still voluntary, but tracked permanently through a DMR/NMFS dealer database. Reporting compliance from known dealers was approximately 65%.

2004: DMR implemented a mandatory dealer reporting system to identify licensed dealers who buy from harvesters (first point of contact). Landings are reported are aggregated by month. There remain problems with identifying dealers who buy from harvesters but are not required to have licenses (out-of-state and restaurants), fishermen who directly sell their catch to consumers rather than licensed dealers, and non-commercial harvest which is not recorded in the licensing system.

DMR Port Sampling Program

Initiated in August 1966, the program was designed to survey the Maine lobster fishery using a stratified multistage sampling program (Thomas 1973, Botsford et al. 1986, Scheirer et al. 2004). This program allows for unbiased estimates of total catch and effort by strata. Monthly expanded estimates have been generated through this stratified sampling program from 1967 to present. Each month, 10 dealers are randomly selected from a list of potential buying stations that have been verified as buying from a minimum of five fishermen. On each selected sampling day, fishermen selling their catch at the dealer are interviewed for catch and effort information; the catch is counted, and a biological sub-sample of the catch is examined.

Monthly-expanded estimates are a function of pounds surveyed (LB), potential dealers open for the month (PD), potential days fishing (DF) and days sampled (DS): .

$$annual\_\exp anded\_estimate = \sum \frac{(LB)*(PD)*(DF)}{DS}$$

Over the 42-year time series, expansion factors DF and DS have varied without trend while the PD has changed by month and year. Independent of expansion factors, annual pounds surveyed have increased nearly threefold over the time-series.

Proposed Alternate Landings

Based on the port-sampling index, reported landings were increased by 32%, or 117.2 million pounds, for the period 1997 to 2003 to create an alternate landings stream for the State of Maine (Table 2). Each month and statistical area was proportionally adjusted based on the new annual estimate. We used the average ratio of expanded estimates of landings to the reported landings for the period 1967 through 1996 (1.40) as the expansion factor for landings in the period 1997 to 2003. Adjusted landings were better correlated with the port sampling expanded estimates ($r=0.99$, $p= 0.000$ versus $r = 0.94$, $p= 0.000$), and the residual pattern of the regression model was reduced (Figure 2).

Works Cited

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Scheirer, K., Y. Chen and C. Wilson (2003) A comparitive study of American lobster fishery sea and port sampling programs in Maine: 1998-2000. Fish. Res. 68:343-350.

Thomas, J.C. (1973) An analysis of the commercial lobster (Homarus americanus) fishery along the Coast of Maine, August 1966 through December 1970. NOAA Tech. Rep. SSRF-667.

Table 1. Ratio of Maine port sampling estimated landings to reported landings from 1967 through 2006. White shading are ratios less than 0.6, grey 0.6 to 1.0 and black 1.0.

	Month								
YEAR	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1967	0.23	0.91	0.85	0.43	0.42	0.43	0.34	0.72	0.06
1968	0.50	0.49	0.60	0.64	0.58	0.50	0.85	0.34	0.00
1969	0.72	0.47	0.56	0.49	0.77	0.52	0.52	0.32	0.26
1970	1.03	0.49	0.59	0.49	0.96	1.14	0.61	1.48	0.35
1971	0.28	0.90	0.32	0.50	1.00	0.94	0.66	0.33	0.39
1972	0.36	0.27	0.59	0.41	0.38	0.73	0.85	0.58	0.40
1973	0.26	0.27	0.91	0.70	0.73	0.98	0.62	0.26	0.12
1974	0.32	0.76	1.22	0.67	0.72	0.48	1.10	0.68	0.12
1975	1.81	0.25	0.99	0.26	0.75	0.80	0.78	0.78	0.31
1976	0.39	0.75	0.55	0.61	0.73	1.02	0.74	0.34	0.82
1977	0.77	0.66	0.92	1.06	1.23	0.64	0.45	0.94	0.07
1978	0.74	0.50	0.97	0.40	0.66	1.09	0.42	1.27	0.31
1979	0.28	0.24	0.55	0.38	0.64	0.45	0.52	0.73	0.30
1980	0.00	0.61	0.36	0.80	0.59	0.57	0.72	0.02	0.19
1981	0.04	0.54	0.83	0.64	0.76	0.67	0.34	0.36	0.39
1982	0.82	0.53	1.06	0.40	0.67	0.93	0.66	0.39	0.09
1983	0.65	0.43	0.53	0.47	0.90	0.39	0.53	0.99	0.09
1984	0.00	0.31	0.98	0.67	0.56	0.59	0.85	0.37	0.61
1985	0.30	0.35	0.61	0.32	0.57	0.55	0.75	0.48	0.00
1986	0.40	1.15	0.36	0.32	0.48	0.18	0.51	0.27	0.66
1987	0.39	0.50	0.42	0.75	0.80	0.79	0.27	0.72	0.36
1988	0.42	1.14	0.43	0.40	0.75	0.54	0.28	1.16	0.63
1989	0.82	0.47	0.38	0.50	0.63	0.53	1.10	0.76	0.25
1990	0.39	0.87	1.13	0.60	0.35	0.72	0.41	0.32	0.00
1991	0.96	0.11	0.18	1.02	0.66	1.10	0.57	0.21	0.64
1992	0.70	0.30	0.40	0.54	1.16	1.22	0.43	0.41	0.36
1993	1.76	0.50	1.62	0.71	0.34	0.37	0.76	0.66	0.03
1994	0.45	0.65	0.29	1.14	0.71	0.32	0.41	0.42	0.17
1995	0.00	0.27	0.56	0.46	0.74	0.50	0.63	0.19	0.00
1996	0.90	1.23	0.47	0.66	1.03	0.64	0.29	0.18	0.15
1997	1.45	1.07	0.40	0.49	1.11	1.21	0.73	0.26	1.32
1998	1.18	0.60	0.78	0.66	0.84	1.35	1.12	0.49	0.52
1999	0.35	0.83	0.63	1.27	0.99	0.94	0.87	0.80	0.31
2000	0.49	0.98	0.29	1.30	0.76	0.73	1.09	1.66	0.36
2001	0.34	0.71	1.19	0.92	0.64	0.98	1.37	1.11	0.67
2002	0.94	0.91	1.12	0.81	0.74	1.38	0.84	0.66	0.45
2003	0.17	0.50	1.07	1.63	1.29	1.67	1.01	0.56	0.89
2004	1.13	0.61	0.39	0.84	0.81	0.78	0.54	0.50	0.84
2005	0.56	0.51	0.49	0.73	0.89	0.61	0.97	0.66	1.27
2006	0.14	0.86	0.68	0.84	0.74	0.97	0.84	0.70	0.75

Table 2. Reported landings from Maine DMR and NMFS landings programs, expanded estimates based on the port sampling program and alternate Maine landings. Maine landings were adjusted from 1997 to 2003 based on the 1967 to 1997 index of expanded estimates to reported landings (shadowed area).

	Reported Landings	Expanded Estimates	Alternate Catch
1967	16,489,195	9,337,186	16,489,195
1968	20,501,732	11,318,130	20,501,732
1969	19,834,780	10,346,561	19,834,780
1970	18,172,269	14,683,297	18,172,269
1971	17,558,351	11,680,064	17,558,351
1972	16,256,467	9,308,811	16,256,467
1973	17,044,194	9,725,691	17,044,194
1974	16,457,666	11,948,339	16,457,666
1975	17,017,411	11,161,224	17,017,411
1976	19,001,053	13,024,306	19,001,053
1977	18,487,138	14,078,707	18,487,138
1978	19,130,459	13,714,879	19,130,459
1979	22,131,235	11,066,734	22,131,235
1980	21,977,691	11,398,082	21,977,691
1981	22,631,614	12,214,508	22,631,614
1982	22,730,253	13,934,954	22,730,253
1983	21,684,916	12,766,878	21,684,916
1984	19,545,682	11,312,671	19,545,682
1985	20,125,177	10,069,128	20,125,177
1986	19,704,317	7,641,431	19,704,317
1987	19,747,766	12,217,699	19,747,766

	Reported Landings	Expanded Estimates	Alternate Catch
1988	21,739,067	13,092,824	21,739,067
1989	23,368,719	14,861,211	23,368,719
1990	28,068,238	13,819,798	28,068,238
1991	30,788,646	20,482,272	30,788,646
1992	26,830,448	19,829,365	26,830,448
1993	29,926,464	16,081,206	29,926,464
1994	38,948,867	21,140,056	38,948,867
1995	37,208,324	18,772,213	37,208,324
1996	36,083,443	22,347,848	36,083,443
1997	47,023,271	40,788,938	57,105,655
1998	47,036,836	42,086,701	58,922,557
1999	53,494,418	47,829,179	66,962,189
2000	57,151,327	53,652,064	75,114,389
2001	48,617,693	42,781,931	59,895,898
2002	63,625,745	54,942,432	76,920,940
2003	54,970,948	63,101,405	88,343,730
2004	71,574,344	46,978,803	71,574,344
2005	68,729,813	52,128,357	68,729,813
2006	72,666,861	54,117,067	72,666,861
2007	63,150,731	38,028,405	63,150,731

Figure 1. Time series of Maine's reported landings and expanded estimates from port sampling 1967 through 2007. Landings were adjusted from 1997 to 2003, based on the indexed ratio of the reported landings and the port sampling estimates for 1967 through 1996. Since 2004, dealers are mandated to report monthly for license renewal.

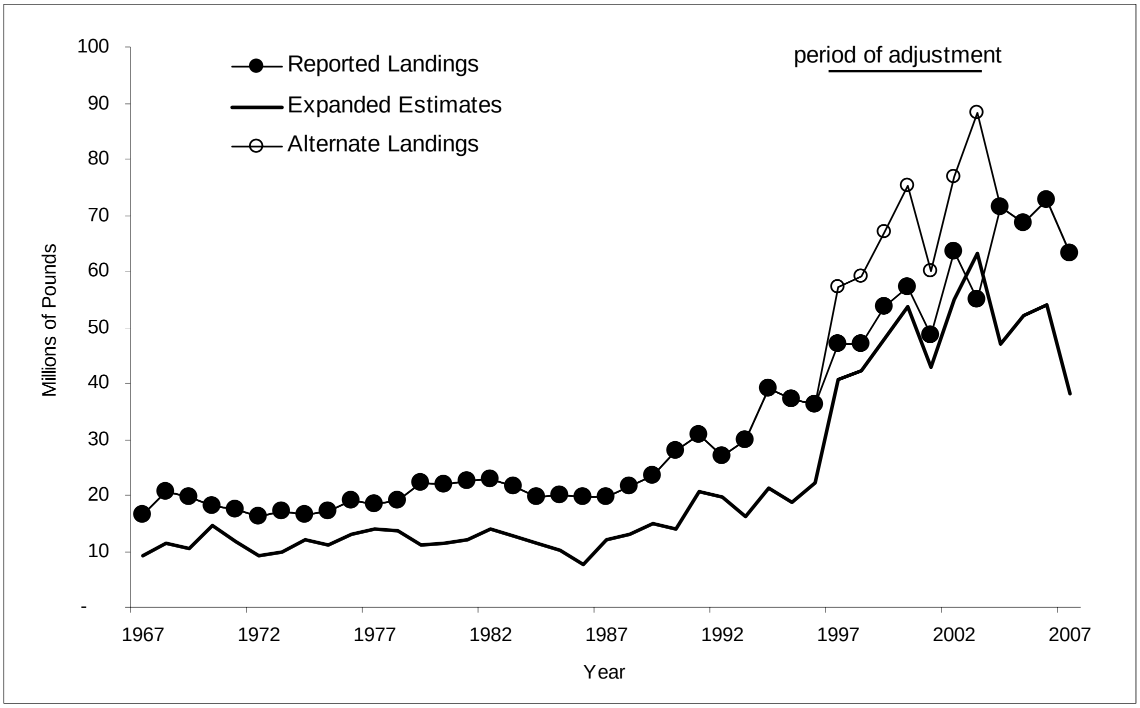
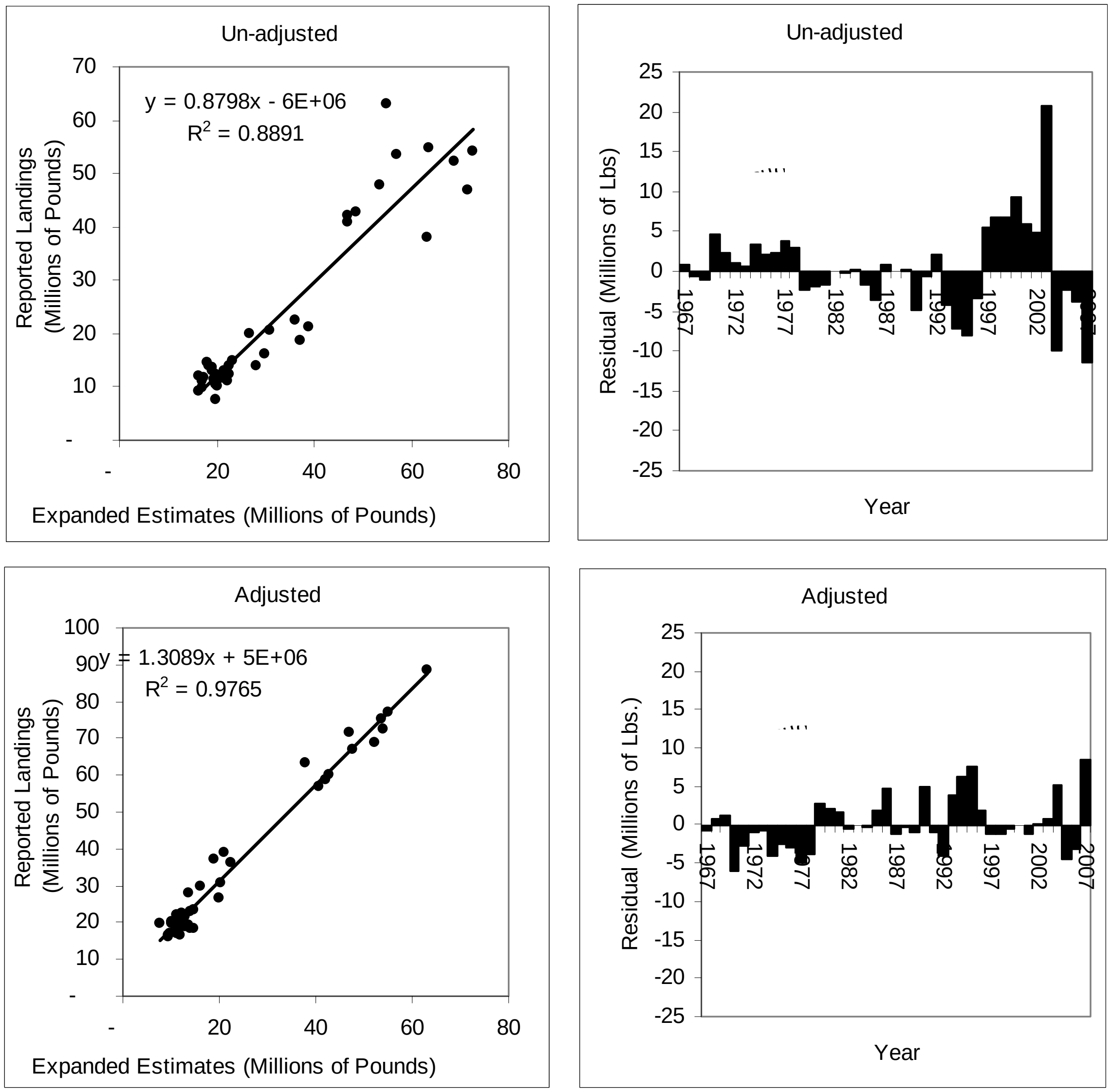


Figure 2. Regression and associated residuals of the reported landings against the port sampling expanded estimates before and after adjustments for the period 1997 to 2003.



Appendix 2: Effects of V-Notching on the Female Lobster Harvest in Rhode Island Waters, 2000-2006

The “North Cape Lobster Restoration Program” began in 2000 with the goal of restocking adult female lobster to mitigate losses from a 1996 oil spill. When the program ended in 2006, a total of 1,323,924 legal-size non-ovigerous female lobster had been notched and released in Rhode Island waters (RI DEM 2007). RI DEM staff documented the incidence of recaptured v-notched lobster during 2000-2005 sea sampling trips (Table 1), and further estimated average fecundity of the notched and un-notched legal and sublegal sized females. Those averages were used to calculate total egg production including and excluding notched females (Table 2). This comparison indicated that the notched females contributed 3-52% of the observed, and by inference the population’s, annual egg production.

RIDEM estimated that the v-notch program resulted in a combination of an increased number of ovigerous females and increased average fecundity of those females (Table 3). Prior to the v-notch program, 24% of females in observed sea-sample catches were ovigerous . This percent increased to an average of 34% in the program years (range 27-40%, Table 3). V-notched eggers constituted up to 14% of observed eggers, indicating that the v-notch program reduced the female harvest by up to 14% of the population. Those females were then able to develop and carry eggs. Additionally, the average fecundity of the released females was estimated to be 10% higher than non-notched legal females (10,263 eggs versus 11,398 eggs, Table 2), increasing the average fecundity of all sea-sampled ovigerous females from about 6,500 eggs to over 8,000 (Table 3, Figure 1), and hence greatly increasing the total eggs produced.

A shortcoming in these computations is that the frequency of v-notched lobster may not be completely random in the population, and the increase in average fecundity may be overestimated. That is, the increase in the number and size of ovigerous females may represent changes in the sampled population but not the entire female population in the area. One way to avoid this “non-random bias” in v-notched versus non-notched females is to examine the overall sex ratio of harvested lobster as a better reflection of the change in harvest patterns due to v-notching. During the years of the v-notch program, the number of females in the observed harvest (market catch) declined from an average of 53% in 1998-2000, to 48% in 2001-2003 when v-notching began, to 41% in 2004-2005 at the height of the program. Prior to 1998, harvests averaged 56% female, showing a historic trend that favored females in the market (Figure 2). The change in female harvest from 53% just prior to the program to 41% at the end of the program represents a 24% decline ((0.53-0.41)/0.53).

A second way to measure changes in discard rates due to v-notching is to apply the percent v-notched females observed in sea samples to total Rhode Island commercial landings, weighted by statistical area (areas 537, 539, and 616), for each year v-notching occurred. The results show that, in the context of total landings, the percent of v-notched females represented a conservation of 5-16% of the available legal-size females in 2000-2004; a conservation of 28% in 2005, and a conservation of 22% 2006 (Figure 3).

The effect of this v-notch program on the conservation-discard rate of the fishery in the area was of short duration, but the magnitude of effect for the entire Southern New England stock (Figure 4) was great enough to require that two selection curves be generated for the stock-wide model analyses, reflecting conditions before the program (1981-1999) and during the program (2000-2006).

Table 1. Catch characteristics of the observed lobster catch in Rhode Island waters, 1991-2005. Marketed legal catch by sex (columns 2-5) is shown by year along with counts of legal-size females by ovigerous and notched condition (column 7-11), and sublegal-size females (column 12-13). Total ovigerous females (column 14) are the sum of columns 10 and 13, and are repeated in the second column of Table 2. Data provided by RI DEM.

				Legal Size Females						Sublegal Females		Total
YEAR	MARKET MALE	MARKET FEMALE	Sex Ratio %females	EGGERS no vnotch	VNOTCH NonEgger	VNOTCH Egger	NEW VNOTCH	Total EGGERS	Total VNOTCH	NonEgger	EGGERS	Eggers
1991	4052	4965	**0.55**	785	0	0	0	785	0	11119	3388	4173
1992	1787	2516	**0.58**	474	0	0	0	474	0	5743	2244	2718
1993	2092	2694	**0.56**	312	0	0	0	312	0	5364	2674	2986
1994	2400	2835	**0.54**	177	0	0	0	177	0	6144	1709	1886
1995	3313	3954	**0.54**	365	0	0	0	365	0	7919	3195	3560
1996	2884	3732	**0.56**	304	0	0	0	304	0	10423	2719	3023
1997	2650	3467	**0.57**	286	0	0	0	286	0	6867	2866	3152
1998	1949	2815	**0.59**	511	0	0	0	511	0	7362	3927	4438
1999	2540	2950	**0.54**	423	0	0	0	423	0	6849	4812	5235
2000	2334	2060	**0.47**	319	599	54	0	373	653	5493	3252	3625
2001	1549	1701	**0.52**	280	344	74	1	354	419	5062	2330	2684
2002	1436	1161	**0.45**	349	624	525	240	874	1389	2631	2143	3017
2003	1359	1239	**0.48**	247	1284	681	354	928	2319	4382	2079	3007
2004	1190	869	**0.42**	271	1238	932	161	1203	2331	3133	2446	3649
2005	1355	865	**0.39**	341	4173	2133	669	2474	6975	4175	3062	5536

Table 2. Estimated increase in egg production attributed to v-notched females.
The number of observed ovigerous females (column 2), and the number of observed ovigerous females without notches (column 3) were multiplied by average fecundities listed below (column 4-5). The difference (column 6) is shown as a percent of the total without notching (column 5). Data provided by RI DEM.

YEAR	Total Eggers	Total Less notched	Total Eggs*	Total Less notched	Percent Increase in Eggs
1991	4173	4173	28634369	28634369	
1992	2718	2718	18494196	18494196	
1993	2986	2986	19443343	19443343	
1994	1886	1886	12196643	12196643	
1995	3560	3560	23151722	23151722	
1996	3023	3023	19634561	19634561	
1997	3152	3152	20342677	20342677	
1998	4438	4438	29096119	29096119	
1999	5235	5235	33568295	33568295	
2000	3625	3571	23641308	23025837	3%
2001	2684	2610	17868969	17025546	5%
2002	3017	2492	22581631	16597884	26%
2003	3007	2326	22924124	15162348	34%
2004	3649	2717	28260317	17637740	38%
2005	5536	3403	46408710	22097599	52%

Average Fecundity	Mean CL	Eggs*
Sublegal	76.0	6074
Legals	87.5	10263
V-notched	90.0	11398

Table 3. Observed ovigerous females (eggers) in the sampled catch, 1991-2005. Data provided by RI DEM.

				Percent Eggers			Ave Fecundity			Egg Production		
Year	All sizes NonEgger	All sizes Eggers	All Females	All Eggers	Less Notched	Percent Increase	All Eggers	Less notched	Percent Increase	All Eggers	Less Notched	Total % Increase
1991	16084	4173	20257	21%	21%		6862	6862		1414	1414	
1992	8259	2718	10977	25%	25%		6804	6804		1685	1685	
1993	8058	2986	11044	27%	27%		6512	6512		1761	1761	
1994	8979	1886	10865	17%	17%		6467	6467		1123	1123	
1995	11873	3560	15433	23%	23%		6503	6503		1500	1500	
1996	14155	3023	17178	18%	18%		6495	6495		1143	1143	
1997	10334	3152	13486	23%	23%		6454	6454		1508	1508	
1998	10177	4438	14615	30%	30%		6556	6556		1991	1991	
1999	9799	5235	15034	35%	35%		6412	6412		2233	2233	
2000	8152	3625	11777	31%	30%	0.5%	6522	6448	1%	2007	1955	3%
2001	7108	2684	9792	27%	27%	0.8%	6658	6523	2%	1825	1739	5%
2002	4656	3017	7673	39%	32%	6.8%	7485	6660	11%	2943	2163	26%
2003	7259	3007	10266	29%	23%	6.6%	7624	6519	14%	2233	1477	34%
2004	5401	3649	9050	40%	30%	10.3%	7745	6492	16%	3123	1949	38%
2005	9882	5536	15418	36%	22%	13.8%	8383	6494	23%	3010	1433	52%

Figure 1. Average estimated fecundity of ovigerous females with and without v-notching, 1991-2005. Data provided by RI DEM.

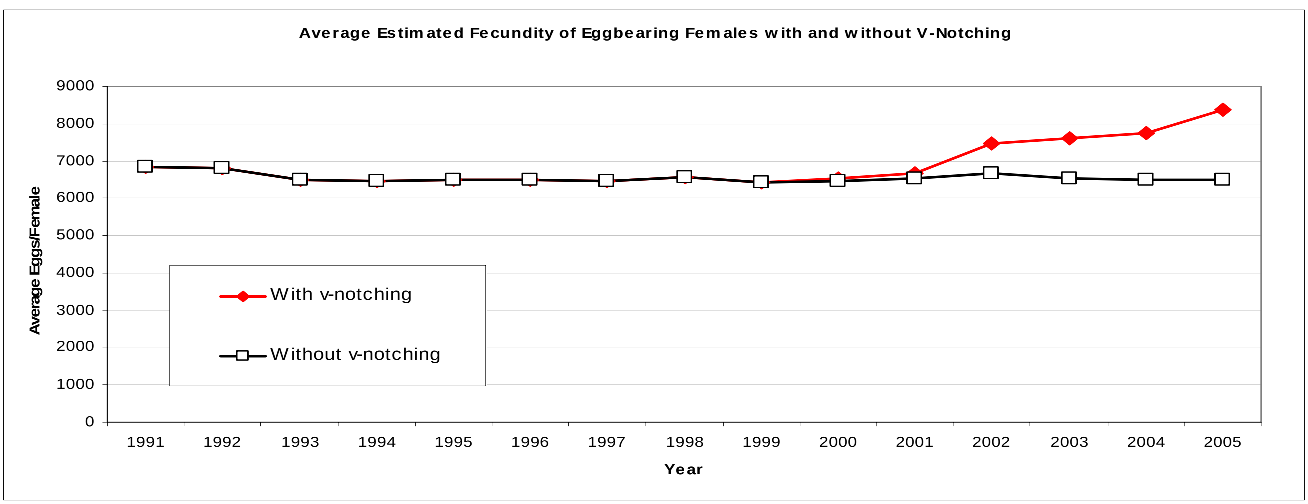


Figure 2. Male and female lobster landings, 1991-2005. Total landings for 1991-2003 were taken from the ASMFC Lobster Database. Total landings for 2004-2005 were estimated from CT, MA, NY, and RI state landings statistics. Total landings were divided by sex using the annual sex ratio recorded from RI sea-sampling, 1991-2005.

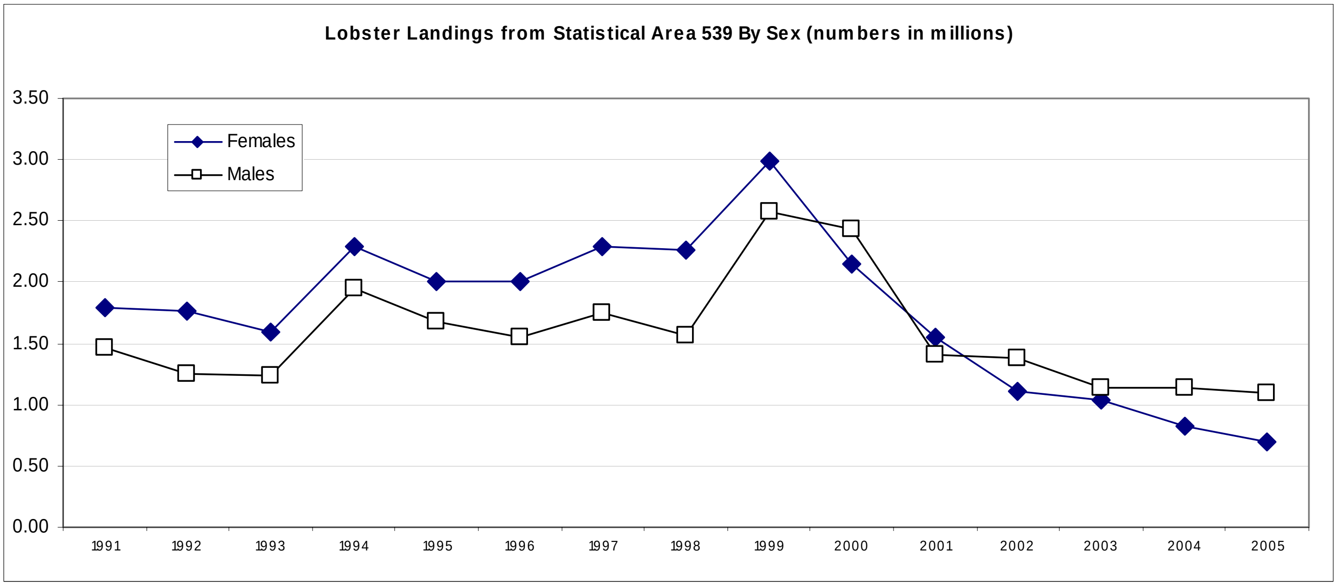


Figure 3. Estimated proportion of v-notched legal-size female lobster in Rhode Island waters. Estimates are based on RI DEM sea samples averaged across all seasons for 2000-2006. Zero proportion for the ten years (1990-1999) before the v-notch program began are shown.

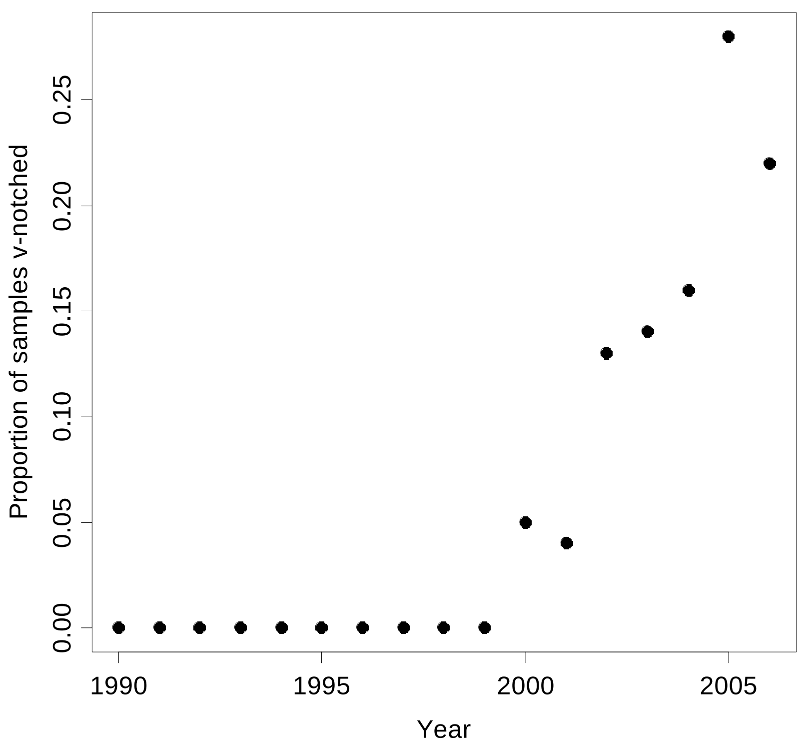
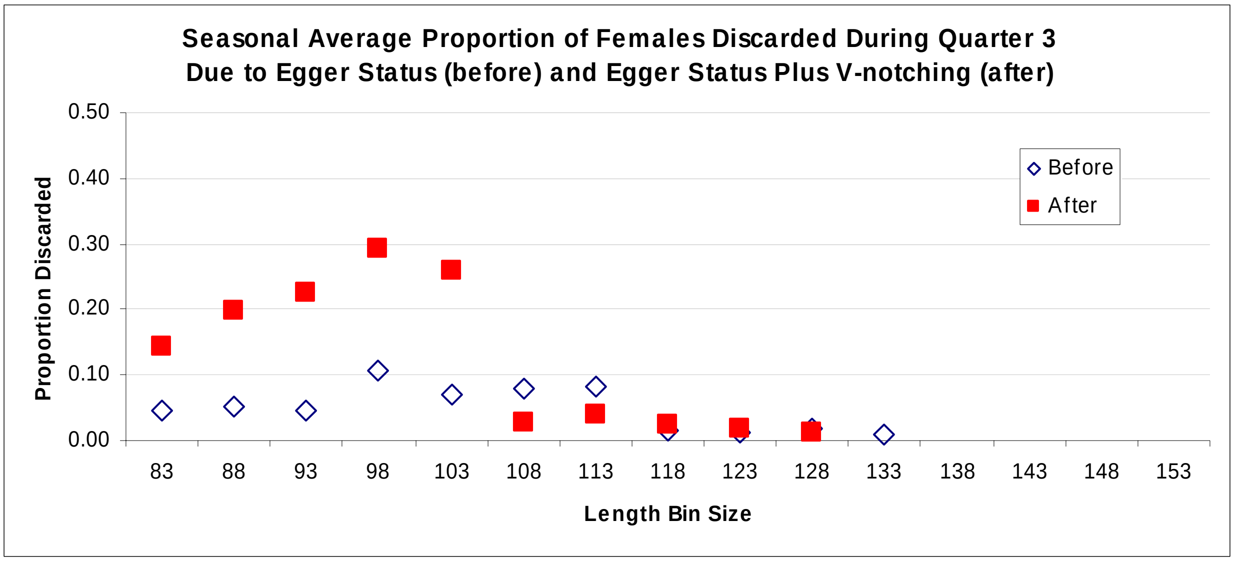


Figure 4. Estimated average proportion of legal-size female lobster discarded in Southern New England waters. Discard proportions are based on Southern New England landings during Quarter 3 (July-September) due to ovigerous status during 1981-1999, before the v-notch program, and ovigerous plus v-notch status during 2000-2006 (after). The maximum difference in proportion discarded by length bin was 22%, and the average difference for all length bins was 8%.



Appendix 3. Additional CSM results.

Table 1. CSM lobster population estimates and data for females in GOM.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	19.23	5.26	24.50		0.85		0.15	1.00	13.20	0.54	0.79
1983	19.09	8.98	28.07		0.62		0.15	0.77	12.22	0.44	0.68
1984	14.02	12.93	26.95	26.51	0.76	0.74	0.15	0.91	13.52	0.50	0.52
1985	15.69	10.79	26.48	27.17	0.73	0.70	0.15	0.88	12.93	0.49	0.59
1986	16.47	10.93	27.40	26.94	0.62	0.70	0.15	0.77	11.92	0.43	0.60
1987	9.77	12.66	22.42	25.43	0.87	0.74	0.15	1.02	12.31	0.55	0.44
1988	19.59	8.05	27.64	25.82	0.80	0.77	0.15	0.95	14.36	0.52	0.71
1989	20.84	10.63	31.47	27.18	0.83	0.84	0.15	0.98	16.74	0.53	0.66
1990	19.79	11.74	31.53	30.21	0.85	0.83	0.15	1.00	17.00	0.54	0.63
1991	18.89	11.57	30.46	31.15	0.76	0.81	0.15	0.91	15.23	0.50	0.62
1992	17.82	12.24	30.07	30.69	0.76	0.79	0.15	0.91	15.12	0.50	0.59
1993	22.70	12.04	34.74	31.76	0.78	0.77	0.15	0.93	17.75	0.51	0.65
1994	33.83	13.62	47.45	37.42	0.61	0.72	0.15	0.76	20.36	0.43	0.71
1995	21.50	22.13	43.63	41.94	0.59	0.66	0.15	0.74	18.20	0.42	0.49
1996	31.62	20.84	52.46	47.85	0.56	0.58	0.15	0.71	21.05	0.40	0.60
1997	28.59	25.85	54.45	50.18	0.58	0.58	0.15	0.73	22.54	0.41	0.53
1998	38.58	26.16	64.74	57.22	0.52	0.55	0.15	0.67	24.74	0.38	0.60
1999	39.25	32.96	72.21	63.80	0.56	0.55	0.15	0.71	29.02	0.40	0.54
2000	34.62	35.47	70.10	69.02	0.43	0.50	0.15	0.58	22.92	0.33	0.49
2001	38.59	39.24	77.83	73.38	0.44	0.48	0.15	0.59	25.91	0.33	0.50
2002	34.70	43.15	77.85	75.26	0.39	0.42	0.15	0.54	23.46	0.30	0.45
2003	7.29	45.41	52.70	69.46	0.85	0.56	0.15	1.00	28.39	0.54	0.14
2004	53.02	19.37	72.38	67.64	0.57	0.60	0.15	0.72	29.49	0.41	0.73
2005	19.01	35.19	54.21	59.76	1.02	0.81	0.15	1.17	32.78	0.60	0.35
2006	26.83	16.68	43.51	56.70	1.22	0.94	0.15	1.37	29.05	0.67	0.62
2007	12.75	10.94	23.68	40.47							
Median 82-03	20.31	12.79	33.14	34.59	0.68	0.70	0.15	0.83	17.37	0.46	0.59
Min 82-03	7.29	5.26	22.42	25.43	0.39	0.42	0.15	0.54	11.92	0.30	0.14
Max 82-03	39.25	45.41	77.85	75.26	0.87	0.84	0.15	1.02	29.02	0.55	0.79
Mean 05-07	19.53	20.94	40.47	52.31	1.12	0.88	0.15	1.27	30.91	0.64	0.48
Mean 04-06	32.96	23.74	56.70	61.37	0.94	0.78	0.15	1.09	30.44	0.56	0.57

Table 2. CSM lobster population estimates and data for males in GOM.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	14.27	7.51	21.78		0.97		0.15	1.12	12.80	0.59	0.66
1983	19.25	7.03	26.28		0.70		0.15	0.85	12.45	0.47	0.73
1984	10.11	11.18	21.29	23.12	0.97	0.88	0.15	1.12	12.44	0.58	0.47
1985	20.27	6.93	27.20	24.92	0.68	0.78	0.15	0.83	12.62	0.46	0.75
1986	14.07	11.81	25.88	24.79	0.69	0.78	0.15	0.84	12.18	0.47	0.54
1987	11.76	11.14	22.90	25.33	0.96	0.78	0.15	1.11	13.32	0.58	0.51
1988	18.82	7.53	26.35	25.04	0.85	0.83	0.15	1.00	14.25	0.54	0.71
1989	24.73	9.63	34.35	27.87	0.68	0.83	0.15	0.83	15.91	0.46	0.72
1990	24.62	14.97	39.59	33.43	0.68	0.74	0.15	0.83	18.41	0.46	0.62
1991	14.28	17.16	31.45	35.13	0.78	0.71	0.15	0.93	15.97	0.51	0.45
1992	19.95	12.41	32.37	34.47	0.73	0.73	0.15	0.88	15.81	0.49	0.62
1993	24.48	13.38	37.86	33.89	0.78	0.76	0.15	0.93	19.37	0.51	0.65
1994	35.20	14.81	50.01	40.08	0.57	0.69	0.15	0.72	20.28	0.41	0.70
1995	23.54	24.41	47.95	45.27	0.51	0.62	0.15	0.66	17.91	0.37	0.49
1996	29.18	24.79	53.97	50.64	0.57	0.55	0.15	0.72	22.05	0.41	0.54
1997	23.10	26.18	49.27	50.39	0.66	0.58	0.15	0.81	22.49	0.46	0.47
1998	25.58	21.76	47.33	50.19	0.67	0.64	0.15	0.82	21.81	0.46	0.54
1999	28.31	20.71	49.02	48.54	0.84	0.73	0.15	0.99	26.29	0.54	0.58
2000	30.70	18.09	48.78	48.38	0.69	0.74	0.15	0.84	22.92	0.47	0.63
2001	30.07	20.94	51.01	49.60	0.79	0.77	0.15	0.94	26.17	0.51	0.59
2002	37.48	19.91	57.38	52.39	0.55	0.68	0.15	0.70	22.70	0.40	0.65
2003	18.82	28.51	47.33	51.91	0.95	0.76	0.15	1.10	27.39	0.58	0.40
2004	39.42	15.67	55.09	53.27	0.76	0.75	0.15	0.91	27.63	0.50	0.72
2005	24.37	22.07	46.44	49.62	1.36	1.02	0.15	1.51	32.71	0.70	0.52
2006	30.49	10.15	40.64	47.39	1.29	1.14	0.15	1.44	27.89	0.69	0.75
2007	9.86	9.54	19.40	35.49							
Median 82-03	23.32	14.89	38.73	37.60	0.70	0.74	0.15	0.85	18.16	0.47	0.60
Min 82-03	10.11	6.93	21.29	23.12	0.51	0.55	0.15	0.66	12.18	0.37	0.40
Max 82-03	37.48	28.51	57.38	52.39	0.97	0.88	0.15	1.12	27.39	0.59	0.75
Mean 05-07	21.57	13.92	35.49	44.17	1.32	1.08	0.15	1.47	30.30	0.70	0.64
Mean 04-06	31.43	15.97	47.39	50.09	1.14	0.97	0.15	1.29	29.41	0.63	0.66

Table 3. CSM lobster population estimates and data for MA DMF survey in GOM.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	7.98	5.46	13.44		0.96		0.15	1.11	7.85	0.58	0.59
1983	11.14	4.38	15.52		0.84		0.15	0.99	8.30	0.53	0.72
1984	8.52	5.75	14.27	14.41	0.97	0.92	0.15	1.12	8.38	0.59	0.60
1985	8.88	4.61	13.49	14.43	1.11	0.97	0.15	1.26	8.57	0.63	0.66
1986	6.19	3.78	9.97	12.58	1.97	1.35	0.15	2.12	8.20	0.82	0.62
1987	9.25	1.16	10.42	11.29	1.85	1.64	0.15	2.00	8.37	0.80	0.89
1988	10.99	1.38	12.37	10.92	1.59	1.80	0.15	1.74	9.36	0.76	0.89
1989	14.26	2.13	16.39	13.06	1.27	1.57	0.15	1.42	11.18	0.68	0.87
1990	11.53	3.90	15.43	14.73	1.15	1.34	0.15	1.30	10.00	0.65	0.75
1991	7.91	4.15	12.07	14.63	1.24	1.22	0.15	1.39	8.12	0.67	0.66
1992	6.98	2.97	9.95	12.48	2.04	1.48	0.15	2.19	8.28	0.83	0.70
1993	11.43	1.07	12.51	11.51	1.26	1.52	0.15	1.41	8.50	0.68	0.91
1994	10.90	3.01	13.91	12.12	1.26	1.52	0.15	1.41	9.44	0.68	0.78
1995	9.22	3.36	12.58	13.00	1.26	1.26	0.15	1.41	8.53	0.68	0.73
1996	8.39	3.05	11.44	12.64	1.63	1.38	0.15	1.78	8.76	0.77	0.73
1997	7.66	1.90	9.57	11.20	1.75	1.55	0.15	1.90	7.54	0.79	0.80
1998	9.91	1.39	11.30	10.77	1.36	1.58	0.15	1.51	7.97	0.71	0.88
1999	10.43	2.46	12.88	11.25	1.47	1.53	0.15	1.62	9.42	0.73	0.81
2000	7.03	2.51	9.55	11.24	1.52	1.45	0.15	1.67	7.08	0.74	0.74
2001	7.06	1.77	8.83	10.42	1.79	1.59	0.15	1.94	7.01	0.79	0.80
2002	6.52	1.24	7.76	8.71	1.77	1.69	0.15	1.92	6.14	0.79	0.84
2003	5.61	1.11	6.72	7.77	2.68	2.08	0.15	2.83	6.02	0.90	0.83
2004	6.43	0.37	6.80	7.10	1.96	2.14	0.15	2.11	5.58	0.82	0.95
2005	6.95	0.80	7.75	7.09	1.78	2.14	0.15	1.93	6.14	0.79	0.90
2006	5.55	1.10	6.65	7.07	1.97	1.90	0.15	2.12	5.47	0.82	0.83
2007	2.87	0.77	3.65	6.02							
Median 82-03	8.70	2.74	12.22	11.81	1.42	1.52	0.15	1.57	8.33	0.72	0.77
Min 82-03	5.61	1.07	6.72	7.77	0.84	0.92	0.15	0.99	6.02	0.53	0.59
Max 82-03	14.26	5.75	16.39	14.73	2.68	2.08	0.15	2.83	11.18	0.90	0.91
Mean 05-07	5.12	0.89	6.02	6.72	1.87	2.02	0.15	2.02	5.80	0.81	0.87
Mean 04-06	6.31	0.76	7.07	7.08	1.90	2.06	0.15	2.05	5.73	0.81	0.89

Table 4. CSM lobster population estimates and data for NEFSC survey in GOM.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	25.52	7.32	32.84		0.88		0.15	1.03	18.15	0.55	0.78
1983	27.20	11.63	38.83		0.60		0.15	0.75	16.37	0.42	0.70
1984	15.61	18.36	33.97	35.22	0.80	0.76	0.15	0.95	17.58	0.52	0.46
1985	27.08	13.11	40.19	37.66	0.60	0.66	0.15	0.75	16.99	0.42	0.67
1986	24.35	18.96	43.31	39.16	0.50	0.63	0.15	0.65	15.89	0.37	0.56
1987	12.28	22.64	34.91	39.47	0.75	0.61	0.15	0.90	17.27	0.49	0.35
1988	27.43	14.19	41.62	39.95	0.68	0.64	0.15	0.83	19.25	0.46	0.66
1989	31.30	18.13	49.43	41.99	0.62	0.68	0.15	0.77	21.46	0.43	0.63
1990	32.88	22.81	55.69	48.91	0.66	0.65	0.15	0.81	25.41	0.46	0.59
1991	25.26	24.58	49.84	51.65	0.68	0.65	0.15	0.83	23.08	0.46	0.51
1992	30.80	21.69	52.48	52.67	0.62	0.65	0.15	0.77	22.65	0.43	0.59
1993	35.75	24.34	60.09	54.14	0.71	0.67	0.15	0.86	28.62	0.48	0.59
1994	58.12	25.43	83.55	65.38	0.51	0.61	0.15	0.66	31.20	0.37	0.70
1995	35.82	43.18	79.00	74.21	0.47	0.56	0.15	0.62	27.58	0.35	0.45
1996	52.41	42.58	94.99	85.85	0.49	0.49	0.15	0.64	34.34	0.36	0.55
1997	44.02	50.12	94.15	89.38	0.55	0.50	0.15	0.70	37.50	0.40	0.47
1998	54.25	46.52	100.77	96.64	0.52	0.52	0.15	0.67	38.58	0.38	0.54
1999	57.13	51.22	108.34	101.09	0.60	0.56	0.15	0.75	45.89	0.42	0.53
2000	58.29	51.05	109.33	106.15	0.48	0.53	0.15	0.63	38.76	0.35	0.53
2001	61.61	58.40	120.01	112.56	0.51	0.53	0.15	0.66	45.06	0.38	0.51
2002	65.65	61.82	127.47	118.94	0.41	0.46	0.15	0.56	40.03	0.31	0.52
2003	20.50	72.81	93.31	113.60	0.83	0.58	0.15	0.98	49.76	0.53	0.22
2004	86.01	34.67	120.68	113.82	0.61	0.62	0.15	0.76	51.54	0.43	0.71
2005	36.44	56.46	92.90	102.30	1.13	0.86	0.15	1.28	59.35	0.64	0.39
2006	51.78	25.72	77.50	97.03	1.21	0.98	0.15	1.36	51.47	0.66	0.67
2007	19.74	19.70	39.44	69.95							
Median 82-03	32.09	24.46	57.89	59.76	0.60	0.61	0.15	0.75	26.49	0.42	0.55
Min 82-03	12.28	7.32	32.84	35.22	0.41	0.46	0.15	0.56	15.89	0.31	0.22
Max 82-03	65.65	72.81	127.47	118.94	0.88	0.76	0.15	1.03	49.76	0.55	0.78
Mean 05-07	35.99	33.96	69.95	89.76	1.17	0.92	0.15	1.32	55.41	0.65	0.53
Mean 04-06	58.08	38.95	97.03	104.38	0.98	0.82	0.15	1.13	54.12	0.58	0.59

Table 5. CSM lobster population estimates and data for females in GBK.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	1.53	2.91	4.44		0.22		0.15	0.37	0.81	0.18	0.34
1983	1.40	3.07	4.48		0.20		0.15	0.35	0.75	0.17	0.31
1984	1.80	3.16	4.96	4.62	0.20	0.20	0.15	0.35	0.82	0.17	0.36
1985	1.63	3.51	5.14	4.86	0.18	0.19	0.15	0.33	0.80	0.16	0.32
1986	2.05	3.68	5.73	5.27	0.16	0.18	0.15	0.31	0.80	0.14	0.36
1987	2.03	4.19	6.22	5.69	0.16	0.17	0.15	0.31	0.84	0.13	0.33
1988	1.43	4.57	6.01	5.98	0.14	0.15	0.15	0.29	0.73	0.12	0.24
1989	1.23	4.49	5.73	5.98	0.17	0.16	0.15	0.32	0.84	0.15	0.22
1990	2.41	4.15	6.56	6.10	0.16	0.16	0.15	0.31	0.92	0.14	0.37
1991	1.51	4.79	6.31	6.20	0.16	0.16	0.15	0.31	0.85	0.14	0.24
1992	2.86	4.64	7.50	6.79	0.16	0.16	0.15	0.31	1.04	0.14	0.38
1993	1.57	5.49	7.06	6.95	0.16	0.16	0.15	0.31	0.97	0.14	0.22
1994	0.64	5.18	5.82	6.79	0.18	0.17	0.15	0.33	0.90	0.15	0.11
1995	1.47	4.18	5.65	6.17	0.20	0.18	0.15	0.35	0.95	0.17	0.26
1996	1.15	3.99	5.13	5.53	0.23	0.20	0.15	0.38	0.96	0.19	0.22
1997	2.89	3.53	6.42	5.73	0.17	0.20	0.15	0.32	0.95	0.15	0.45
1998	2.12	4.64	6.77	6.11	0.16	0.19	0.15	0.31	0.94	0.14	0.31
1999	1.18	4.96	6.13	6.44	0.15	0.16	0.15	0.30	0.80	0.13	0.19
2000	3.46	4.54	8.00	6.97	0.12	0.14	0.15	0.27	0.82	0.10	0.43
2001	2.21	6.13	8.34	7.49	0.12	0.13	0.15	0.27	0.87	0.10	0.26
2002	2.35	6.37	8.72	8.35	0.14	0.13	0.15	0.29	1.07	0.12	0.27
2003	3.20	6.52	9.72	8.93	0.12	0.13	0.15	0.27	1.03	0.11	0.33
2004	0.81	7.41	8.22	8.89	0.17	0.14	0.15	0.32	1.18	0.14	0.10
2005	1.63	5.98	7.62	8.52	0.18	0.16	0.15	0.33	1.17	0.15	0.21
2006	0.25	5.47	5.73	7.19	0.25	0.20	0.15	0.40	1.20	0.21	0.04
2007	1.03	3.82	4.85	6.06							0.21
Median 82-03	1.71	4.52	6.17	6.14	0.16	0.16	0.15	0.31	0.86	0.14	0.31
Min 82-03	0.64	2.91	4.44	4.62	0.12	0.13	0.15	0.27	0.73	0.10	0.11
Max 82-03	3.46	6.52	9.72	8.93	0.23	0.20	0.15	0.38	1.07	0.19	0.45
Mean 05-07	0.97	5.09	6.06	7.26	0.22	0.18	0.15	0.37	1.18	0.18	0.16
Mean 04-06	0.90	6.29	7.19	8.20	0.20	0.17	0.15	0.35	1.18	0.17	0.12

Table 6. CSM lobster population estimates and data for males in GBK.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	0.88	1.26	2.14		0.61		0.15	0.76	0.92	0.43	0.41
1983	1.16	1.00	2.16		0.40		0.15	0.55	0.66	0.31	0.54
1984	0.90	1.25	2.14	2.15	0.60	0.54	0.15	0.75	0.90	0.42	0.42
1985	0.75	1.02	1.76	2.02	0.68	0.56	0.15	0.83	0.81	0.46	0.42
1986	1.45	0.77	2.22	2.04	0.51	0.60	0.15	0.66	0.83	0.37	0.65
1987	1.93	1.14	3.07	2.35	0.43	0.54	0.15	0.58	1.00	0.33	0.63
1988	0.85	1.72	2.57	2.62	0.43	0.46	0.15	0.58	0.83	0.33	0.33
1989	1.20	1.44	2.64	2.76	0.46	0.44	0.15	0.61	0.91	0.34	0.46
1990	1.00	1.43	2.44	2.55	0.73	0.54	0.15	0.88	1.18	0.49	0.41
1991	1.11	1.01	2.13	2.40	0.93	0.71	0.15	1.08	1.21	0.57	0.52
1992	1.44	0.72	2.17	2.24	0.93	0.86	0.15	1.08	1.23	0.57	0.67
1993	1.13	0.74	1.87	2.05	0.99	0.95	0.15	1.14	1.10	0.59	0.60
1994	0.89	0.60	1.49	1.84	0.70	0.87	0.15	0.85	0.70	0.47	0.60
1995	0.93	0.64	1.57	1.64	0.64	0.77	0.15	0.79	0.69	0.44	0.59
1996	0.89	0.72	1.60	1.55	0.61	0.65	0.15	0.76	0.68	0.43	0.55
1997	1.35	0.75	2.11	1.76	0.46	0.57	0.15	0.61	0.73	0.35	0.64
1998	1.13	1.14	2.27	1.99	0.43	0.50	0.15	0.58	0.75	0.33	0.50
1999	0.78	1.27	2.05	2.14	0.62	0.51	0.15	0.77	0.88	0.43	0.38
2000	1.27	0.95	2.22	2.18	0.58	0.54	0.15	0.73	0.91	0.41	0.57
2001	1.16	1.07	2.23	2.17	0.67	0.62	0.15	0.82	1.02	0.46	0.52
2002	1.01	0.99	2.00	2.15	0.66	0.64	0.15	0.81	0.91	0.45	0.51
2003	1.05	0.89	1.94	2.06	0.43	0.59	0.15	0.58	0.64	0.33	0.54
2004	0.79	1.08	1.87	1.94	0.54	0.55	0.15	0.69	0.73	0.39	0.42
2005	0.40	0.94	1.34	1.72	0.66	0.55	0.15	0.81	0.61	0.45	0.30
2006	0.42	0.59	1.01	1.41	1.19	0.80	0.15	1.34	0.66	0.65	0.42
2007	0.79	0.27	1.06	1.14							
Median 82-03	1.08	1.01	2.14	2.15	0.61	0.58	0.15	0.76	0.89	0.43	0.53
Min 82-03	0.75	0.60	1.49	1.55	0.40	0.44	0.15	0.55	0.64	0.31	0.33
Max 82-03	1.93	1.72	3.07	2.76	0.99	0.95	0.15	1.14	1.23	0.59	0.67
Mean 05-07	0.54	0.60	1.14	1.42	0.92	0.67	0.15	1.07	0.63	0.55	0.36
Mean 04-06	0.54	0.87	1.41	1.69	0.80	0.63	0.15	0.95	0.67	0.50	0.38

Table 7. CSM lobster population estimates and data for females in SNE.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982											
1983											
1984	4.42	3.07	7.49	7.49	0.78	0.78	0.15	0.93	3.83	0.51	0.59
1985	4.74	2.93	7.67	7.58	0.81	0.79	0.15	0.96	4.00	0.52	0.62
1986	5.99	2.94	8.93	8.03	0.70	0.76	0.15	0.85	4.24	0.47	0.67
1987	4.41	3.80	8.21	8.27	0.79	0.76	0.15	0.94	4.20	0.51	0.54
1988	5.51	3.20	8.71	8.62	0.99	0.83	0.15	1.14	5.17	0.59	0.63
1989	9.65	2.77	12.42	9.78	0.76	0.85	0.15	0.91	6.25	0.50	0.78
1990	7.15	4.96	12.11	11.08	0.97	0.91	0.15	1.12	7.11	0.59	0.59
1991	5.60	3.93	9.52	11.35	0.81	0.85	0.15	0.96	4.99	0.52	0.59
1992	7.46	3.62	11.08	10.91	0.77	0.85	0.15	0.92	5.63	0.51	0.67
1993	7.94	4.38	12.32	10.98	0.70	0.76	0.15	0.85	5.84	0.47	0.64
1994	5.38	5.25	10.63	11.35	1.34	0.94	0.15	1.49	7.43	0.70	0.51
1995	12.71	2.38	15.10	12.68	1.12	1.05	0.15	1.27	9.62	0.64	0.84
1996	12.59	4.22	16.81	14.18	1.04	1.17	0.15	1.19	10.29	0.61	0.75
1997	11.06	5.07	16.13	16.01	1.32	1.16	0.15	1.47	11.20	0.69	0.69
1998	9.41	3.72	13.13	15.36	1.34	1.23	0.15	1.49	9.18	0.70	0.72
1999	5.45	2.97	8.42	12.56	1.10	1.25	0.15	1.25	5.32	0.63	0.65
2000	5.02	2.39	7.42	9.66	0.97	1.14	0.15	1.12	4.35	0.59	0.68
2001	3.27	2.42	5.70	7.18	1.05	1.04	0.15	1.20	3.51	0.62	0.57
2002	2.22	1.72	3.93	5.68	0.73	0.92	0.15	0.88	1.93	0.49	0.56
2003	1.93	1.62	3.55	4.39	0.62	0.80	0.15	0.77	1.55	0.44	0.54
2004	2.24	1.64	3.87	3.79	0.73	0.69	0.15	0.88	1.88	0.49	0.58
2005	1.84	1.61	3.45	3.63	0.95	0.77	0.15	1.10	2.00	0.58	0.53
2006	2.13	1.15	3.28	3.54	0.81	0.83	0.15	0.96	1.72	0.52	0.65
2007	2.36	1.26	3.62	3.45							0.65
Median 82-03	5.55	3.14	9.23	10.34	0.89	0.88	0.15	1.04	5.25	0.56	0.64
Min 82-03	1.93	1.62	3.55	4.39	0.62	0.76	0.15	0.77	1.55	0.44	0.51
Max 82-03	12.71	5.25	16.81	16.01	1.34	1.25	0.15	1.49	11.20	0.70	0.84
Mean 05-07	2.11	1.34	3.45	3.54	0.88	0.80	0.15	1.03	1.86	0.55	0.61
Mean 04-06	2.07	1.47	3.54	3.65	0.83	0.76	0.15	0.98	1.87	0.53	0.59

Table 8. CSM lobster population estimates and data for males in SNE.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982											
1983											
1984	3.03	1.15	4.19		1.198		0.15	1.35	2.77	0.66	0.72
1985	2.86	1.08	3.94		1.1085		0.15	1.26	2.50	0.63	0.73
1986	3.69	1.11	4.81	4.31	1.0395	1.12	0.15	1.19	2.94	0.61	0.77
1987	2.71	1.45	4.16	4.30	1.3935	1.18	0.15	1.54	2.97	0.71	0.65
1988	4.36	0.88	5.23	4.73	1.193	1.21	0.15	1.34	3.45	0.66	0.83
1989	5.16	1.35	6.52	5.30	1.169	1.25	0.15	1.32	4.25	0.65	0.79
1990	5.22	1.72	6.94	6.23	1.256	1.21	0.15	1.41	4.71	0.68	0.75
1991	4.73	1.68	6.42	6.63	1.214	1.21	0.15	1.36	4.27	0.67	0.74
1992	4.52	1.62	6.14	6.50	1.486	1.32	0.15	1.64	4.51	0.73	0.74
1993	5.47	1.18	6.65	6.40	1.45	1.38	0.15	1.60	4.84	0.73	0.82
1994	7.08	1.33	8.41	7.07	1.5085	1.48	0.15	1.66	6.22	0.74	0.84
1995	6.19	1.57	7.76	7.61	1.5055	1.49	0.15	1.66	5.74	0.74	0.80
1996	8.17	1.47	9.64	8.60	1.3645	1.46	0.15	1.51	6.81	0.71	0.85
1997	6.25	2.10	8.36	8.59	1.2265	1.37	0.15	1.38	5.59	0.67	0.75
1998	6.48	2.09	8.57	8.86	1.7715	1.45	0.15	1.92	6.78	0.79	0.76
1999	6.06	1.24	7.30	8.08	1.9	1.63	0.15	2.05	5.93	0.81	0.83
2000	4.05	0.92	4.97	6.95	1.5935	1.76	0.15	1.74	3.76	0.76	0.81
2001	3.10	0.86	3.97	5.41	1.9729	1.82	0.15	2.12	3.26	0.82	0.78
2002	2.81	0.48	3.29	4.07	1.6595	1.74	0.15	1.81	2.53	0.77	0.86
2003	2.38	0.53	2.91	3.39	1.4385	1.69	0.15	1.59	2.11	0.72	0.82
2004	2.12	0.59	2.71	2.97	1.646	1.58	0.15	1.80	2.08	0.77	0.78
2005	2.16	0.45	2.61	2.74	2.6899	1.92	0.15	2.84	2.34	0.90	0.83
2006	2.29	0.47	2.76	2.69	1.396	1.91	0.15	1.55	1.97	0.71	0.83
2007	2.08	0.59	2.66	2.68							0.78
Median 82-03	4.63	1.28	6.28	6.45	1.42	1.42	0.15	1.57	4.26	0.72	0.79
Min 82-03	2.38	0.48	2.91	3.39	1.04	1.12	0.15	1.19	2.11	0.61	0.65
Max 82-03	8.17	2.10	9.64	8.86	1.97	1.82	0.15	2.12	6.81	0.82	0.86
Mean 05-07	2.18	0.50	2.68	2.70	2.04	1.92	0.15	2.19	2.15	0.81	0.81
Mean 04-06	2.19	0.50	2.69	2.80	1.91	1.81	0.15	2.06	2.13	0.79	0.81

Table 9. CSM lobster population estimates and data for CT DEP survey in SNE.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982											
1983											
1984	2.14	1.44	3.57		0.94		0.15	1.09	2.06	0.58	0.60
1985	2.41	1.19	3.60		0.76		0.15	0.91	1.81	0.50	0.67
1986	2.55	1.43	3.99	3.72	0.89	0.87	0.15	1.04	2.22	0.56	0.64
1987	2.75	1.39	4.15	3.91	1.03	0.90	0.15	1.18	2.52	0.61	0.66
1988	2.64	1.27	3.91	4.01	1.69	1.20	0.15	1.84	3.03	0.78	0.68
1989	4.42	0.61	5.03	4.36	1.25	1.32	0.15	1.40	3.41	0.68	0.88
1990	4.02	1.22	5.24	4.73	1.34	1.43	0.15	1.49	3.68	0.70	0.77
1991	4.00	1.16	5.16	5.15	1.10	1.23	0.15	1.25	3.25	0.63	0.77
1992	3.76	1.47	5.23	5.21	1.35	1.26	0.15	1.50	3.67	0.70	0.72
1993	5.98	1.15	7.13	5.84	0.94	1.13	0.15	1.09	4.10	0.57	0.84
1994	6.30	2.39	8.68	7.01	1.74	1.34	0.15	1.89	6.82	0.79	0.73
1995	9.83	1.28	11.12	8.98	1.78	1.49	0.15	1.93	8.81	0.79	0.88
1996	11.06	1.58	12.64	10.81	1.68	1.73	0.15	1.83	9.79	0.77	0.88
1997	9.04	1.98	11.02	11.59	2.13	1.87	0.15	2.28	9.29	0.84	0.82
1998	7.92	1.09	9.01	10.89	2.18	2.00	0.15	2.33	7.65	0.85	0.88
1999	4.21	0.85	5.06	8.36	1.67	2.00	0.15	1.82	3.91	0.77	0.83
2000	2.50	0.81	3.31	5.79	1.87	1.91	0.15	2.02	2.67	0.81	0.76
2001	1.95	0.43	2.38	3.58	2.89	2.14	0.15	3.04	2.16	0.91	0.82
2002	1.57	0.11	1.68	2.46	1.51	2.09	0.15	1.66	1.24	0.74	0.94
2003	1.30	0.32	1.62	1.89	1.77	2.05	0.15	1.92	1.28	0.79	0.80
2004	1.56	0.23	1.79	1.70	1.66	1.64	0.15	1.81	1.38	0.77	0.87
2005	0.81	0.29	1.10	1.50	5.01	2.81	0.15	5.16	1.41	1.28	0.74
2006	1.29	0.02	1.31	1.40	3.47	3.38	0.15	3.62	1.23	0.94	0.98
2007	0.43	0.03	0.46	0.96							0.93
Median 82-03	3.88	1.21	5.04	5.18	1.59	1.46	0.15	1.74	3.33	0.76	0.79
Min 82-03	1.30	0.11	1.62	1.89	0.76	0.87	0.15	0.91	1.24	0.50	0.60
Max 82-03	11.06	2.39	12.64	11.59	2.89	2.14	0.15	3.04	9.79	0.91	0.94
Mean 05-07	0.84	0.12	0.96	1.29	4.24	3.09	0.15	4.39	1.32	1.11	0.88
Mean 04-06	1.22	0.18	1.40	1.53	3.38	2.61	0.15	3.53	1.34	1.00	0.86

Table 10. CSM lobster population estimates and data for RI DEM survey in SNE.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	1.93	0.39	2.32		1.384		0.15	1.53	1.65	0.71	0.83
1983	1.66	0.50	2.16		1.59		0.15	1.74	1.63	0.76	0.77
1984	2.43	0.37	2.80	2.43	1.55	1.51	0.15	1.70	2.10	0.75	0.87
1985	2.15	0.51	2.65	2.54	1.4145	1.52	0.15	1.56	1.91	0.72	0.81
1986	2.39	0.55	2.94	2.80	1.497	1.49	0.15	1.65	2.16	0.74	0.81
1987	2.81	0.56	3.37	2.98	0.862	1.26	0.15	1.01	1.83	0.54	0.83
1988	3.11	1.22	4.33	3.54	1.016	1.13	0.15	1.17	2.61	0.60	0.72
1989	3.54	1.34	4.88	4.19	1.03	0.97	0.15	1.18	2.97	0.61	0.73
1990	3.11	1.49	4.60	4.60	1.4205	1.16	0.15	1.57	3.31	0.72	0.68
1991	2.96	0.94	3.90	4.46	1.288	1.25	0.15	1.44	2.68	0.69	0.76
1992	3.21	0.92	4.13	4.21	1.217	1.31	0.15	1.37	2.75	0.67	0.78
1993	4.51	1.04	5.55	4.53	1.162	1.22	0.15	1.31	3.61	0.65	0.81
1994	4.18	1.48	5.66	5.11	1.3025	1.23	0.15	1.45	3.91	0.69	0.74
1995	4.55	1.31	5.86	5.69	1.2195	1.23	0.15	1.37	3.91	0.67	0.78
1996	5.05	1.48	6.53	6.02	1.1175	1.21	0.15	1.27	4.16	0.64	0.77
1997	4.17	1.82	5.99	6.13	1.36	1.23	0.15	1.51	4.22	0.71	0.70
1998	4.94	1.31	6.24	6.26	1.791	1.42	0.15	1.94	4.96	0.79	0.79
1999	5.02	0.88	5.90	6.04	1.8775	1.68	0.15	2.03	4.77	0.81	0.85
2000	3.31	0.76	4.07	5.40	2.1314	1.93	0.15	2.28	3.43	0.84	0.81
2001	2.57	0.40	2.97	4.31	2.3564	2.12	0.15	2.51	2.58	0.87	0.86
2002	1.47	0.23	1.70	2.91	1.5315	2.01	0.15	1.68	1.27	0.74	0.86
2003	0.66	0.31	0.98	1.88	1.2225	1.70	0.15	1.37	0.65	0.67	0.68
2004	0.87	0.24	1.12	1.27	1.327	1.36	0.15	1.48	0.78	0.70	0.78
2005	1.36	0.25	1.62	1.24	1.346	1.30	0.15	1.50	1.13	0.70	0.84
2006	1.33	0.36	1.69	1.47	0.977	1.22	0.15	1.13	0.99	0.59	0.79
2007	2.27	0.54	2.81	2.04							0.81
Median 82-03	3.11	0.90	4.10	4.39	1.37	1.28	0.15	1.52	2.72	0.71	0.78
Min 82-03	0.66	0.23	0.98	1.88	0.86	0.97	0.15	1.01	0.65	0.54	0.68
Max 82-03	5.05	1.82	6.53	6.26	2.36	2.12	0.15	2.51	4.96	0.87	0.87
Mean 05-07	1.65	0.39	2.04	1.58	1.16	1.26	0.15	1.31	1.06	0.65	0.81
Mean 04-06	1.19	0.29	1.47	1.33	1.22	1.29	0.15	1.37	0.97	0.66	0.80

Table 11. CSM lobster population estimates and data for NEFSC survey in SNE.

Year	Recruit Abund. (Millions)	Post-recruit Abund. (Millions)	Total Abund. (Millions)	3-Year Average (millions)	Fishing Mortality (F, y-1)	3-Year Average (y-1)	Natural Mortality (M, y-1)	Total Mortality (Z, y-1)	Landings (millions)	Landings / Total Abund.	Stock Fraction Recruits
1982	2.52	2.15	4.67		0.57		0.15	0.72	1.91	0.41	0.54
1983	2.88	2.27	5.14		0.60		0.15	0.75	2.19	0.43	0.56
1984	2.88	2.41	5.30	5.04	0.67	0.62	0.15	0.82	2.44	0.46	0.54
1985	3.05	2.31	5.36	5.27	0.80	0.69	0.15	0.95	2.78	0.52	0.57
1986	4.75	2.07	6.81	5.82	0.57	0.68	0.15	0.72	2.79	0.41	0.70
1987	1.55	3.30	4.85	5.68	0.96	0.78	0.15	1.11	2.82	0.58	0.32
1988	4.11	1.60	5.71	5.79	0.81	0.78	0.15	0.96	2.98	0.52	0.72
1989	6.85	2.18	9.03	6.53	0.67	0.81	0.15	0.82	4.13	0.46	0.76
1990	5.24	3.98	9.21	7.98	0.81	0.76	0.15	0.96	4.83	0.52	0.57
1991	3.37	3.51	6.88	8.37	0.72	0.73	0.15	0.87	3.33	0.48	0.49
1992	5.01	2.86	7.87	7.99	0.70	0.74	0.15	0.85	3.72	0.47	0.64
1993	2.93	3.36	6.29	7.01	0.69	0.70	0.15	0.84	2.96	0.47	0.47
1994	1.99	2.70	4.70	6.29	1.08	0.82	0.15	1.23	2.93	0.62	0.42
1995	4.52	1.37	5.88	5.62	0.65	0.81	0.15	0.80	2.64	0.45	0.77
1996	4.65	2.64	7.28	5.95	0.62	0.78	0.15	0.77	3.15	0.43	0.64
1997	4.10	3.37	7.47	6.88	0.63	0.63	0.15	0.78	3.28	0.44	0.55
1998	3.04	3.42	6.46	7.07	0.80	0.68	0.15	0.95	3.35	0.52	0.47
1999	2.29	2.48	4.77	6.23	0.85	0.76	0.15	1.00	2.57	0.54	0.48
2000	3.25	1.75	5.00	5.41	0.56	0.74	0.15	0.71	2.02	0.40	0.65
2001	1.86	2.45	4.32	4.70	0.69	0.70	0.15	0.84	2.03	0.47	0.43
2002	1.99	1.85	3.84	4.39	0.78	0.68	0.15	0.93	1.95	0.51	0.52
2003	2.35	1.52	3.87	4.01	0.65	0.70	0.15	0.80	1.73	0.45	0.61
2004	1.92	1.75	3.67	3.79	0.74	0.72	0.15	0.89	1.80	0.49	0.52
2005	1.83	1.51	3.34	3.63	0.84	0.74	0.15	0.99	1.79	0.53	0.55
2006	1.80	1.24	3.04	3.35	0.72	0.77	0.15	0.87	1.47	0.48	0.59
2007	1.74	1.27	3.01	3.13							0.58
Median 82-03	3.04	2.43	5.53	5.89	0.69	0.73	0.15	0.84	2.80	0.47	0.55
Min 82-03	1.55	1.37	3.84	4.01	0.56	0.62	0.15	0.71	1.73	0.40	0.32
Max 82-03	6.85	3.98	9.21	8.37	1.08	0.82	0.15	1.23	4.83	0.62	0.77
Mean 05-07	1.79	1.34	3.13	3.37	0.78	0.75	0.15	0.93	1.63	0.51	0.57
Mean 04-06	1.85	1.50	3.35	3.59	0.77	0.74	0.15	0.92	1.68	0.50	0.56