Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-29

2005 Massachusetts Lobster Monitoring and Stock Status Report

R. Glenn, T. Pugh, J. Barber, and D. Chosid

Massachusetts Division of Marine Fisheries
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I. Introduction

Background

The commercial lobster fishery is the most economically important fishery conducted within the territorial waters of the Commonwealth of Massachusetts. The inshore lobster fleet is comprised mainly of small vessels (22 to 42 feet) that make day trips in nearshore waters (less than 12 miles). The primary gear employed in the lobster fishery is traps, which has accounted for greater than 97% of the territorial landings since 1981. In 2004 a total of 7,077,114 pounds of lobster were landed in Massachusetts territorial waters, with an estimated $31,847,014 ex-vessel value.

The uniqueness of the Massachusetts coastline provides a geographic barrier between the southern end of the Gulf of Maine, the western end of Georges Bank, and the northern end of Southern New England waters. This barrier creates distinct hydrographical conditions in each region that have a profound effect on the life history traits of lobsters, especially growth and reproduction. Through ongoing research and monitoring the Massachusetts Division of Marine Fisheries (*MarineFisheries)* has discerned geographic variation in morphology, size-distribution, migratory behavior, growth rate, fecundity, and maturity. These differences in lobster life history parameters observed north, east, and south of Cape Cod are used as a basis to define three separate stocks of lobsters within our coastal waters: Gulf of Maine, Outer Cape Cod which is part of the Georges Bank stock, and Southern New England. The ASMFC Lobster Management plan specifies 3 lobster management areas in Massachusetts coastal waters which overlap to varying degrees with the stock areas (Figure 1). Management area designations were based primarily on the percent contribution from different stock components, but the manner in which the fisheries have been prosecuted were also taken into consideration.

Given the scale and importance of the lobster fishery, *MarineFisheries* carries out a comprehensive monitoring program of the American lobster resource and fishery in Massachusetts' coastal and nearshore waters. We employ a 4-tiered approach designed to characterize key population parameters necessary for assessing the health of each stock. The four tiers are: the Fisheries Statistics Program, the Commercial Lobster Trap Sampling Program, the Inshore Bottom Trawl Survey, and the Juvenile Lobster Suction Sampling Survey. The purpose of this report is to provide a profile of the condition of each the three stocks of lobsters that occur in Massachusetts coastal waters. All data presented are collated, analyzed, and discussed relative to the three stock units/management areas: Massachusetts portion of the Gulf of Maine/Lobster Management Area 1 (GOM), Massachusetts portion of Georges Bank/Lobster Management Area OCC (OCC), and the

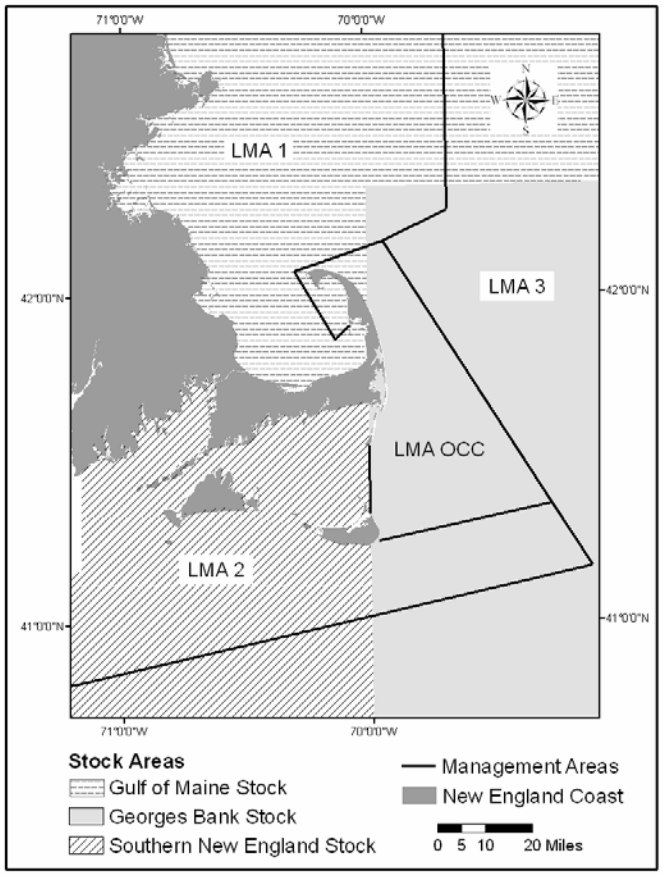


Figure 1. Map of three lobster stock units and overlapping lobster management areas (LMA) in Massachusetts coastal waters.

Massachusetts portion of Southern New England/Lobster Management Area 2 (SNE).

Fisheries Statistics Program

MarineFisheries monitors commercial and recreational lobster harvest via an annual catch reporting system administered by the Fisheries Statistics Project. Chapter 130, Mass. G.L., Section 33, requires any person licensed to fish for lobsters to file an annual report of their catch by January 31 of the preceding calendar year. The objective of this program is to characterize harvest and fishing effort in the Massachusetts lobster fishery. Data collected from this program are critical to the assessment and subsequent management of American lobster in Massachusetts coastal and adjacent federal waters.

Methods

The annual lobster catch report requests the following information relevant to the lobster fishery: 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. Recreational fishermen are asked to report on their permit renewal application form the number of lobsters taken during the previous year, hours dived and the maximum number of traps fished. Project personnel sort, edit, tabulate and interpret data from all reports received. All catch and effort data collected are reported by DMF Statistical Reporting Area (Figure 2). DMF Statistical areas 1 through 8 (inshore) and 19 (offshore) comprise the Massachusetts portion of the Gulf of Maine stock (GOM), and together comprise National Marine Fisheries Service (NMFS) statistical area 514. DMF statistical areas 9 (inshore) and 18 (offshore) comprise the Massachusetts portion of the Georges Bank stock (OCC), and combine together to create NMFS statistical area 521. DMF statistical areas 10, 12, 13, 14, (inshore) combine together to comprise NMFS statistical area 538, and 16 (offshore) comprises NMFS statistical area 537 in its entirety, together these areas comprise the Massachusetts portion of the Southern New England stock (SNE).

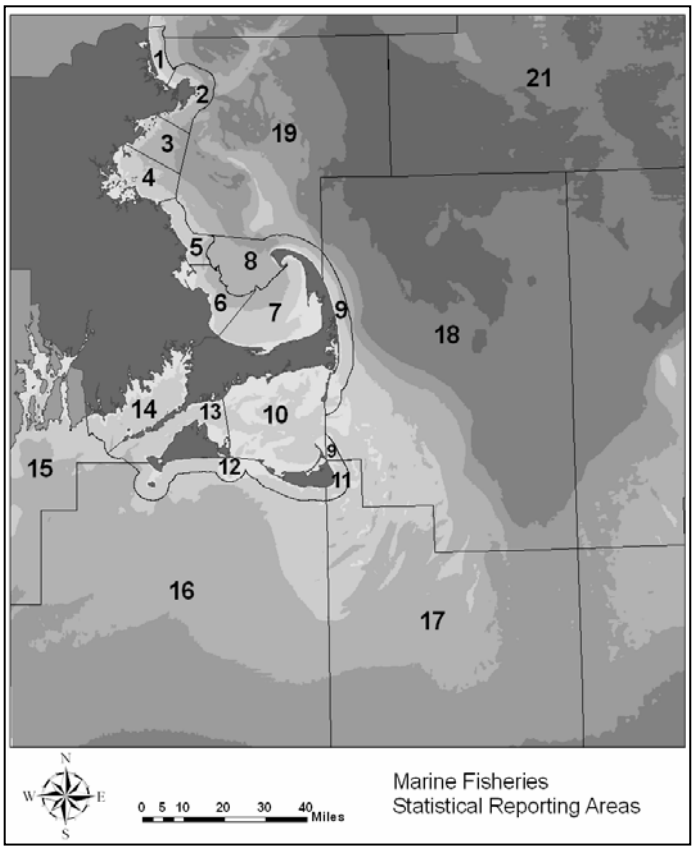


Figure 2. Map of DMF inshore and offshore statistical reporting areas.

Landings data are presented for each area from 1981 through 2004. Effort data were not collected with sufficient spatial resolution to allow collation into each stock area prior to 1994. As such, effort data are only presented from 1994 through 2004.

Commercial Trap Sea-Sampling Program

MarineFisheries instituted fisheries dependent at-sea trap sampling in 1981 as a long-term coastwide monitoring program in order to produce biological and catch per unit effort data on the American lobster resource. A sea sampling/survey design was chosen by which both catch per unit effort and biological data could be collected temporally and areally with sufficient precision for stock assessments. The objective of the trap sampling program is to assess variations in pop-ulation parameters due to environmental factors, fishing pressure, and regulatory changes. Trends in data collected from 1981 through 2004 will be presented for three stock units: GOM, OCC, and SNE.

Methods

The coastal lobster fishery is sampled by placing at-sea observers aboard vessels of volunteer commercial lobstermen during normal lobstering operations. Sampling is conducted in six regions throughout coastal Massachusetts (Figure 3A): Cape Ann, Beverly-Salem, Boston Harbor, Cape Cod Bay, Outer Cape Cod, and Buzzards Bay. Commercial trap sampling is conducted primarily within the territorial waters of the Commonwealth of Massachusetts, except where lobstering activities of cooperating commercial lobstermen exceeded territorial boundaries (see Figure 3B). These six regions were chosen to provide coverage of the major lobstering regions of the state. Where possible, multiple lobstering operations were observed to enhance areal coverage. The locations of all traps sampled from 2000 through 2004 are depicted in Figure 3B.

Each region is sampled a minimum of once per month per region during the major lobstering season, May-November. Sampling trips are day trips, and the sampler records information for a minimum of 100 traps per day. The actual number of traps sampled per day typically ranges from 100 to 400, depending on the lobstering operation being observed. The annual number of trips completed and traps sampled by stock area are depicted in Table 1.

Table 1. Number of trips and traps sampled by stock area from 1981 to 2004.

	GOM		OCC		SNE	
	# of Trips	# of Traps	# of Trips	# of Traps	# of Trips	# of Traps
1981	25	4,512	6	566	5	659
1982	27	4,402	6	1,108	6	641
1983	30	5,406	13	2,193	10	1,182
1984	34	6,705	11	1,330	10	1,130
1985	55	11,158	13	1,691	12	1,174
1986	58	11,447	11	1,828	12	1,660
1987	63	11,021	13	1,710	13	1,846
1988	63	11,843	14	1,575	13	2,201
1989	64	11,711	14	1,517	14	1,819
1990	68	12,713	15	1,575	14	1,871
1991	62	13,335	11	1,468	14	1,563
1992	63	14,190	14	1,835	14	1,960
1993	55	11,475	16	2,137	14	2,532
1994	54	10,370	13	1,965	10	1,550
1995	54	12,120	14	2,079	11	1,619
1996	52	11,842	14	2,001	11	1,543
1997	86	21,792	14	1,927	10	1,025
1998	52	11,876	15	2,018	14	1,964
1999	53	11,278	14	1,678	12	2,146
2000	54	12,281	14	1,912	15	3,058
2001	52	11,880	13	1,705	14	3,149
2002	57	12,768	18	1,842	15	2,717
2003	62	14,699	18	1,951	9	1,889
2004	51	11,588	16	1,920	12	2,858

Sea samplers record: catch in number of lobsters, number of trap hauls, set-over days, trap and bait type, carapace length (to the nearest mm), sex, shell hardness, culls and other shell damage, external gross pathology, mortality, presence of extruded ova on females (ovigerous), and presence of v-notches for females. Trap locations were recorded from LORAN or GPS. Depth at mean low water for each trap location was recorded from NOAA navigational charts as a coastwide standard to avoid variability from tidal fluctuations.

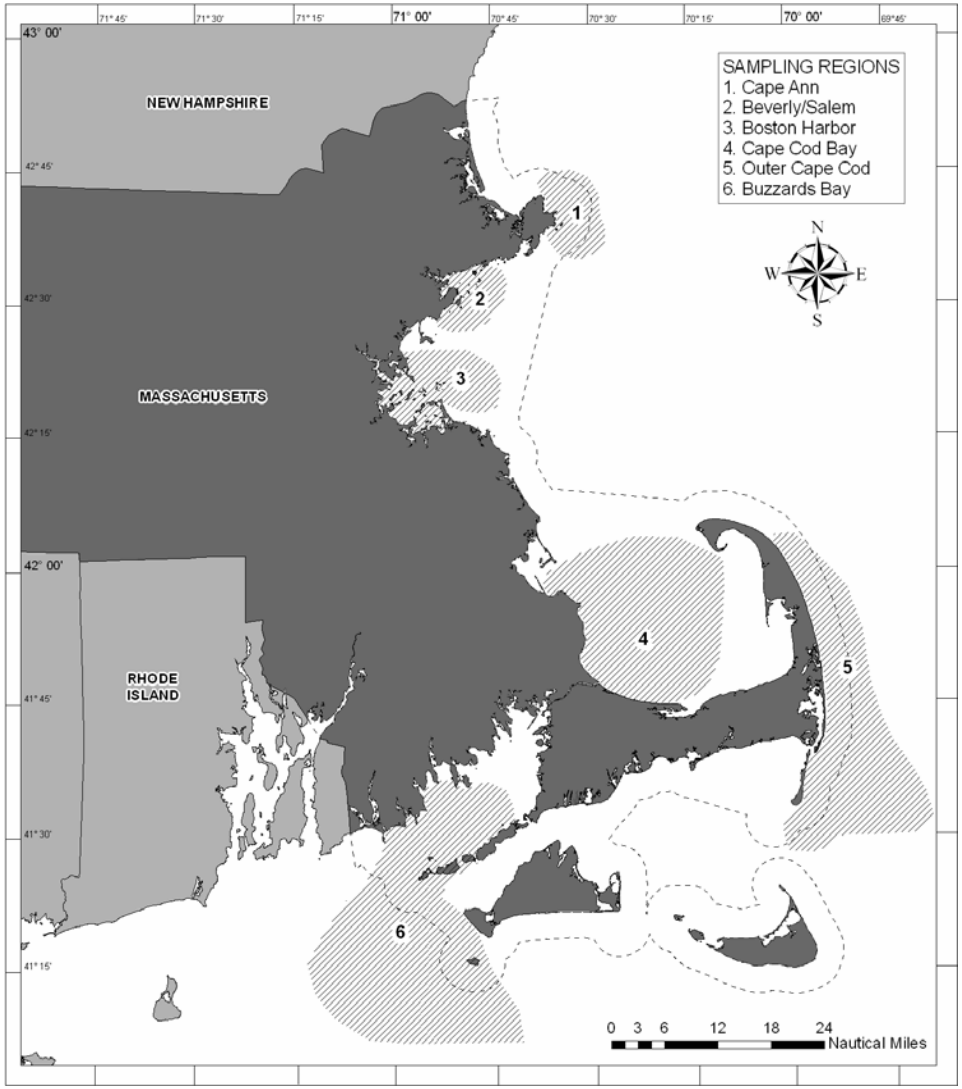
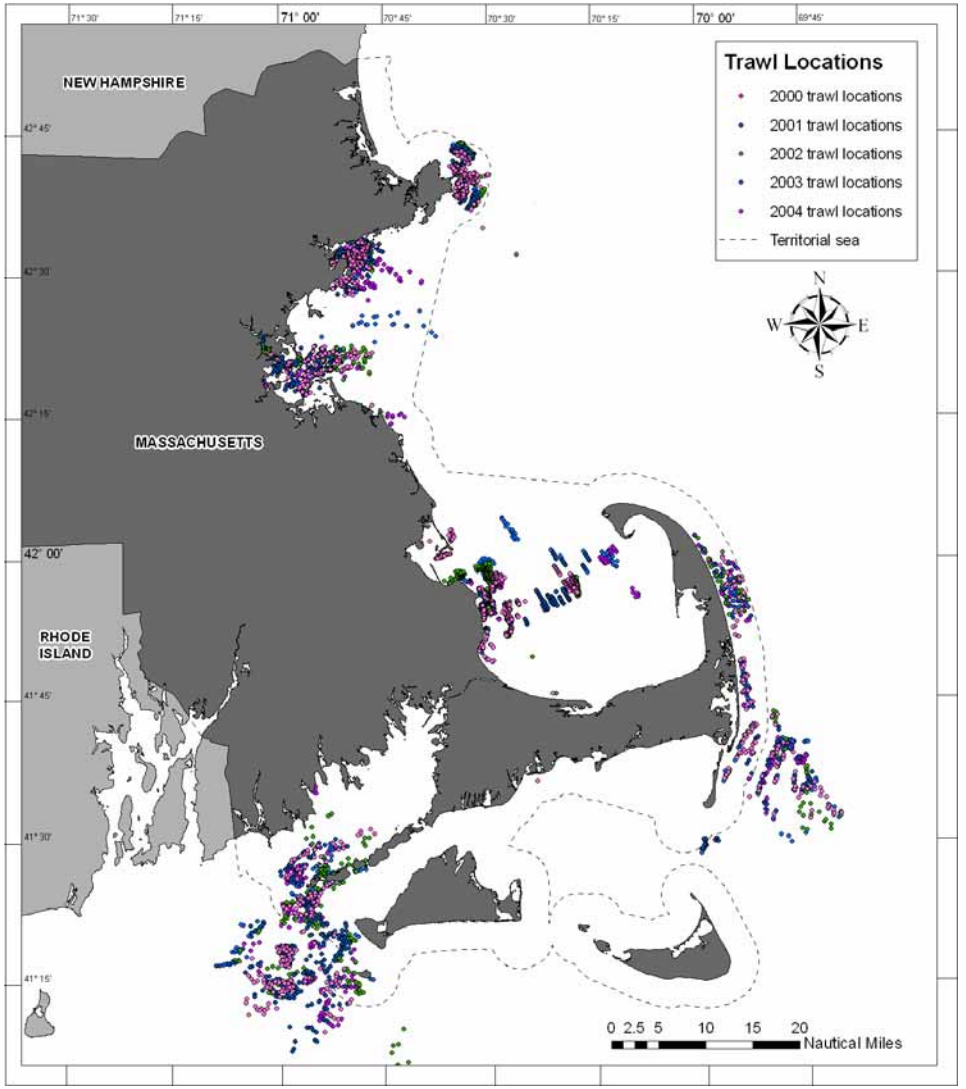


Figure 3A) Map showing the six commercial trap sampling regions.



3B) Locations of traps sampled from 2000-2004.

Unless specified otherwise, the term “legal” or “legal sized” lobster include all lobster equal to or greater than the minimum size in effect at the time of sampling. “Marketable” lobsters are defined as legal size lobsters that are non-ovigerous and are not v-notched (according to the appropriate regional definition for v-notch). “Sub-legal” lobsters are all lobsters less than the minimum size in effect at the time of sampling.

A culled lobster is defined as a lobster with some evidence of major damage to one or both of its chelipeds (claws). Evidence of major damage includes missing claws, newly regenerating claws (rubbery buds), or regenerating claws (at least one molt since injury).

Samplers record v-notches in the tails of female lobsters using a standard protocol which classifies v-notches into three categories: sharp notch, old notch, and missing or mutilated flipper. A sharp notch is defined as a straight-sided V without setal hairs. An old notch is a notch on a lobster that has persisted through at least one molt. Old notches are typically irregularly shaped and may have setal hairs.

Data are analyzed relative to the appropriate regional v-notch definition. In GOM there is a “zero-tolerance” definition which means a v-shaped notch of any size with or without setal hairs in the flipper next to and to the right of the center flipper as viewed from the rear of the female lobster when the underside of the lobster is down. In all other areas a v-notch is defined as a "V" shaped notch at least ¼ inch and not greater than a ½ inch in depth and tapering to a sharp point in the flipper next to and to the right of the center flipper as viewed from the rear of the female lobster when the underside of the lobster is down.

A sub-sampling protocol for shell disease was added to the sampling procedure in 2000, and conforms to a coastwide standard protocol established by the ASMFC Lobster Technical Committee. Approximately 50 lobsters are examined each trip for evidence of shell disease and classified into the following categories, based upon the amount of carapace covered with pitting and/or erosions: None = 0%, Low = 1-10%, Moderate = 11-50%, Severe = 51-100%. Date and location coordinates, carapace length, sex, ovigerous condition, and shell hardness are also collected for these lobsters. This sub-sampling protocol is conducted independently of the standard commercial trap sampling during the course of a trip.

Massachusetts Inshore Trawl Survey

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. Tow locations from the 2004 autumn survey are presented in Figure 4. The total number of GOM and SNE inshore trawl surveys completed from 1978-2004 are presented in Table 2.

Lobster Indices

The lobster relative abundance indices only use data collected during the autumn portion of the inshore trawl survey. The reason for this is the increased availability of lobsters to the survey due to warmer bottom water temperatures at this time of year.

The Outer Cape sites (east of Cape Cod and Nantucket, Nantucket Sound) are not included in this assessment due to the inconsistent availability of lobsters resulting from the migratory nature of this stock.

Since 1981, the MA GOM area has had two gauge size (minimum legal lobster size) increases which occurred in 1989 and 1990; the SNE has had three increases occurring in 1989, 1990, and 2003. These changes are incorporated in the legal and sub-legal survey indices calculated over the time series.

Loess smoothing techniques were applied in order to interpolate possible trends in the relative abundance data (Cleveland et. al 1988) This method weights nearest-neighbor data points and runs a quadratic polynomial regression to "smooth" the data (span = 50%, alpha = 0.05). Outliers, as determined by this method, are removed before the data are smoothed.

Figure 4. Location of tows included in the 2004 lobster abundance indices.

Table 2. Number of tows completed annually in the GOM and SNE regions.

	GOM	SNE
1978	40	46
1979	37	48
1980	40	42
1981	40	40
1982	38	43
1983	31	41
1984	38	41
1985	37	44
1986	39	42
1987	38	37
1988	38	25
1989	39	21
1990	39	37
1991	38	36
1992	35	31
1993	34	38
1994	40	43
1995	40	42
1996	37	44
1997	39	38
1998	38	35
1999	34	45
2000	39	44
2001	39	46
2002	37	41
2003	40	40
2004	33	39

Juvenile Lobster Suction Sampling Survey

Early benthic phase (EBP) American lobster, *Homarus americanus,* are juveniles with a carapace length (CL) less than 40 mm (Wahle and Steneck 1991). This group includes newly settled postlarvae (5 - 12 mm, "YOY") and juveniles up to about 3 years old. At this stage in their life history, lobsters are cryptic and rarely leave their shelters, primarily due to the risk of predation (Wahle and Steneck 1992). They are highly substrate selective, occurring mainly in habitats that supply appropriate shelter such as cobble and boulder reefs, as well as eelgrass and peat reefs.

The air-lift suction sampling technique was designed to collect data on EBP lobster density and habitat use. Suction sampling for EBP lobsters has been ongoing for several years in Maine (Wahle and Steneck 1991) and Rhode Island (Wahle 1993). In 1995 *MarineFisheries* initiated a long-term sampling program to quantify the relative abundance of EBP lobster in Massachusetts coastal waters.

Since the program's inception, *MarineFisheries* has conducted suction sampling during the peak larval lobster settlement period (late August to early September) across four regions spanning the Massachusetts coast (Figure 5). This program was designed to address three primary goals: (1) to document critical juvenile lobster nursery habitat in our nearshore waters, (2) to monitor year class strength and, (3) to eventually generate a predictive model where the density of EBP lobsters can be used to predict future recruitment to the fishery.

Figure 5. Four regions along the Massachusetts coast that are annually suction sampled for EBP lobsters.

Methods

Preliminary SCUBA surveys were performed in each region to determine suction sampling locations. Sampling sites were selected on the basis of the presence of appropriate substrate, depth, and exposure to predominant currents at each location. In 1995, three sites were sampled in each of three regions: Buzzards Bay, Cape Cod Bay, and Salem Sound. In 1996, only sites in Cape Cod Bay and Buzzards Bay were sampled. In 1997, all but one of the original sites (Peaches Point, Salem Sound) were sampled, and an additional 5 sites were sampled in the Boston Harbor region. In 1998 and 1999 three more sites were added in Buzzards Bay. In 2000, one of the Buzzards Bay sites (Weepecket Island) was eliminated and one site was added to Boston Harbor (Sculpin Ledge Artificial Cobble Reef). In 2001, one more site was added to the Salem Sound area (Browns Island). Since 2001, 18 sites are sampled annually with the following number of sites per region: 3/Salem Sound, 7/Boston Harbor, 3/Cape Cod Bay, and 5/Buzzards Bay (Figure 6).

Sampling was conducted using a diver-operated suction device. Sampling design and equipment was standardized according to the

strategy defined by Wahle (1993). The suction device consisted of a 3" PVC lift tube supplied with air from a SCUBA tank. Samples were air-lifted into a 1.5 mm mesh nylon bag attached to the upper end of the suction tube. At each site, 0.5 m^2 quadrats were haphazardly placed on the substratum at least 2 meters apart until a total of 12 replicates were complete. Large boulders and large patches of sand were avoided. In 1995 samples were primarily taken on cobble substrate, and taken on eelgrass and featureless substrates when available. After 1995, samples were taken only on cobble bottom.

Sampling a quadrat in cobble habitat involved slowly moving the lift tube over the bottom while carefully moving rocks individually. In eelgrass and featureless sediment, the suction tube was simply moved back and forth over the sediment until the entire quadrat had been suctioned. All fauna were carefully identified on the surface, counted, and recorded.

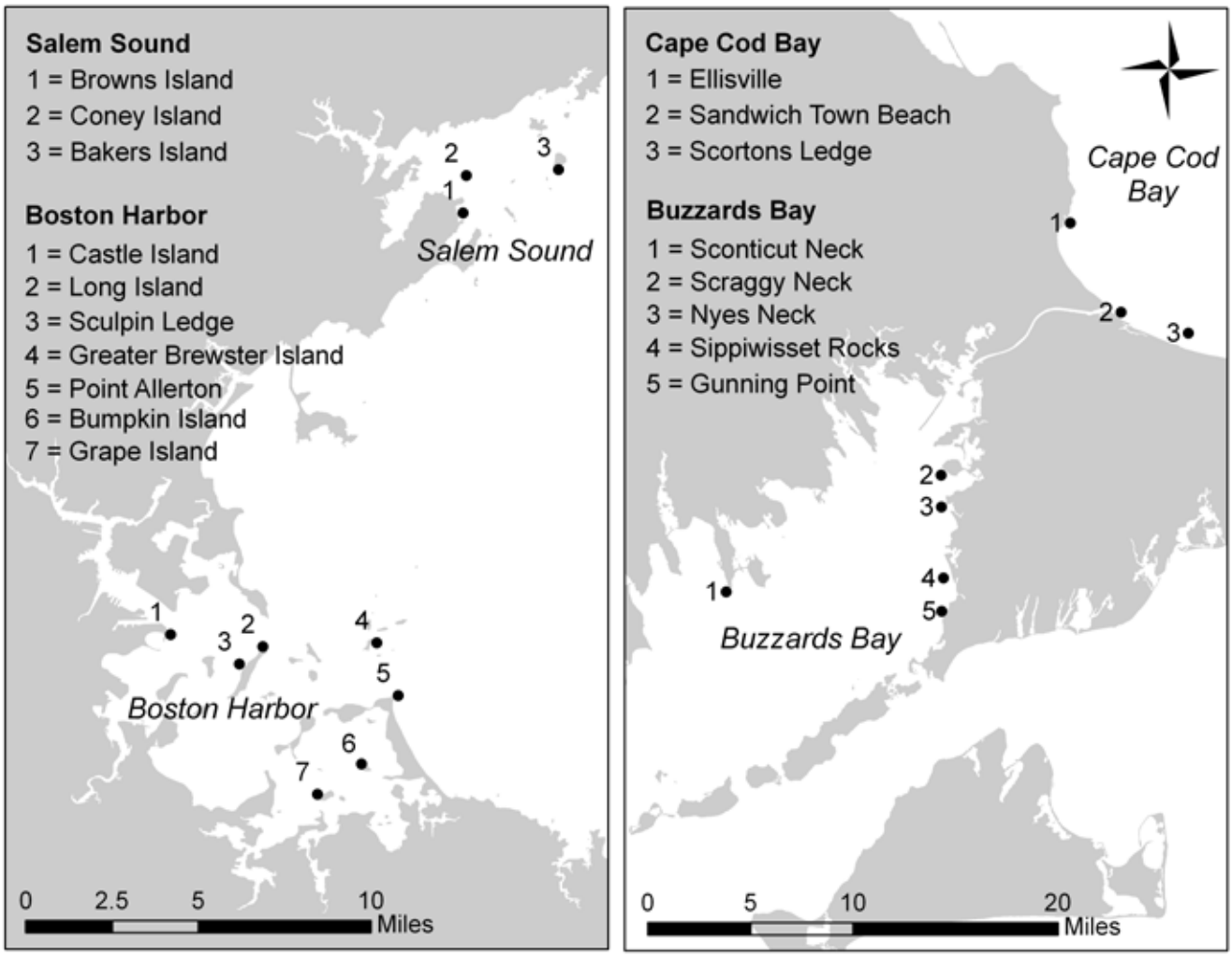


Figure 6. Location of the 18 suction sampling sites in Massachusetts coastal waters.

Gulf of Maine

Fishery Statistics

In 2004, a total of 815 fishermen reported landing 7,342,453 pounds of lobster from 1,208,165 trap hauls in the Massachusetts portion of the Gulf of Maine. These were the second lowest recorded landings since 1981 and 24% below the time series mean.

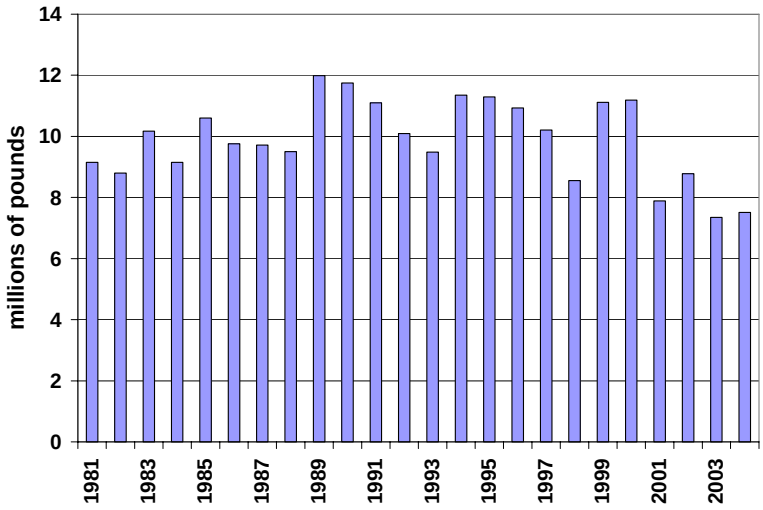


Figure 7. Commercial lobster landings in GOM from Massachusetts territorial waters and adjacent federal waters.

Commercial landings in the Massachusetts portion of the GOM are depicted in Figure 7. Landings gradually increased from 1981 to 1989, where they reached an all time high of 12 million pounds. Between 1990 and 2000 lobster landings remained high varying around an average of 10.6 million pounds. This was followed by a substantial decline in which the catch from 2001 to 2004 accounted for 4 out of the 5 lowest values on record. The observed declines in commercial landings are likely related to the reduced stock abundance in GOM (ASMFC 2006).

Commercial catch in MAGOM stock accounted for 85% of the total Massachusetts landings in 2004, and an average of 88% of the total over the course of the entire time series. From 1990 to 2004, the inshore portion of MAGOM accounted for an average of 81 % of the total catch in this area. The relative contribution of inshore catch and offshore catch to the total landings has remained consistent throughout the time series.

The number of active permits reporting landings has gradually declined from a high of 998 permits in 1994 to a low of 815 permits in 2004 (Table 3). The annual maximum number of traps reported fished has varied without trend around the time series mean of 378,219. The total number of trap hauls has gradually declined from highs observed in the mid-1990's to a time series low value in 2004 (1.2 million). The recent declines in permits and trap hauls represent a slight reduction in fishing effort in the MAGOM stock. This is likely the result of attrition stemming from declining stock abundance and changes in policy related to permit transfers in this area.

Table 3. Number of active permits reporting lobster landings, number of trap hauls, and the annual maximum number of traps fished in the MAGOM, 1994 to 2004.

GOM	Number of Fisherman	Number of Trap Hauls	Annual Maximum Number of Traps
1994	998	1,368,468	372,014
1995	994	1,341,321	375,177
1996	987	1,366,465	387,526
1997	965	1,269,073	381,361
1998	955	1,292,455	388,073
1999	919	1,268,584	377,691
2000	944	1,352,771	381,775
2001	931	1,293,265	373,114
2002	912	1,309,941	390,627
2003	892	1,282,254	378,891
2004	815	1,208,165	354,166
Average	*937*	*1,304,797*	*378,219*

Commercial Trap Sampling

2004 Sampling Season

MarineFisheries staff observed 21,003 lobsters during the 2004 commercial trap sampling season in the Gulf of Maine. Roughly half (53%) of these lobsters were below minimum legal size (83 mm carapace length). The size range of lobsters observed ranged from 30 mm CL to 157 mm CL (Figure 8). Most marketable lobsters (89%) observed were within one molt of minimum legal size (Figure 9).

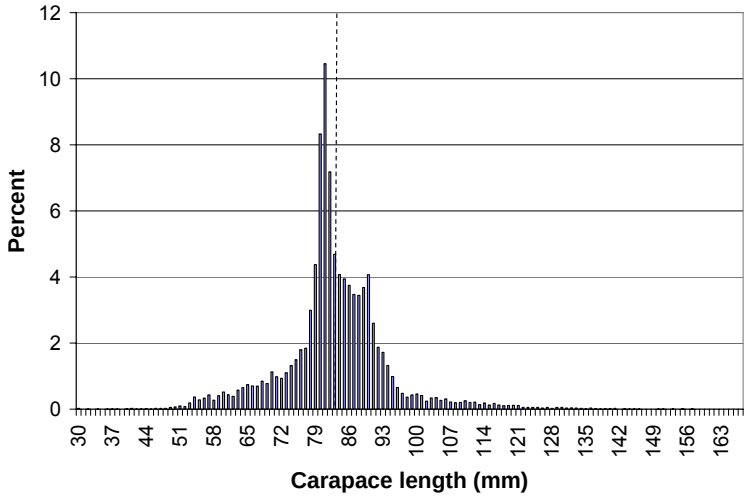


Figure 8. Percent length frequency distribution, 2004 Gulf of Maine. Dashed line represents minimum legal size.

Time Series Trends

Throughout the course of the time series for commercial trap sampling, more than 82% of the marketable catch has been within one molt of minimum legal size (Figure 9). From 1981 to 1988, this percentage increased from 82% to 90%. Since 1989 this percentage has varied around 90%. This high percentage of lobsters within one molt of minimum legal size is indicative of a fishery that is dependent on new recruits.

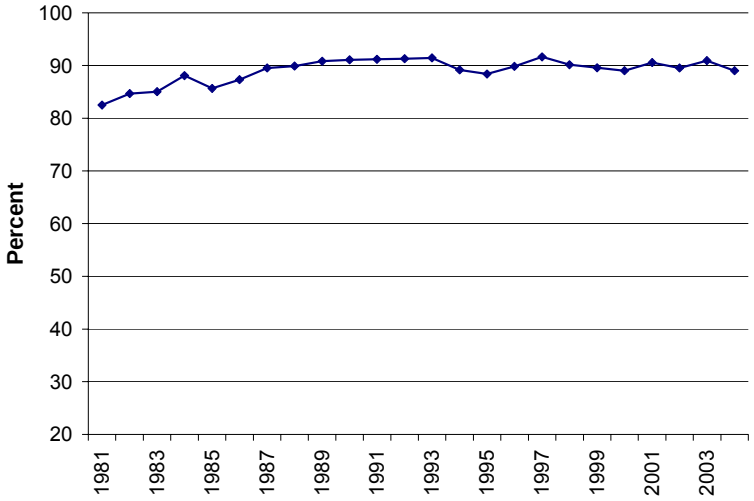


Figure 9. Percentage of the marketable catch within one molt of minimum legal size

The average percent of the female catch bearing eggs has generally increased since the late 1980's and early 1990's (Figure 10). In 2004, 14% of the female catch was egg-bearing, a time series high.

The percentage of the female catch with a v-notch is presented in Figure 11. The percentage of v-notched female lobsters varied without trend between 1981 and 1999, and then has increased steadily since 2000, reaching a time series high of 13.4% in 2004. This trend is due to implementation and increasing compliance with the Area 1 mandatory v-notching regulations that was implemented in 2000.

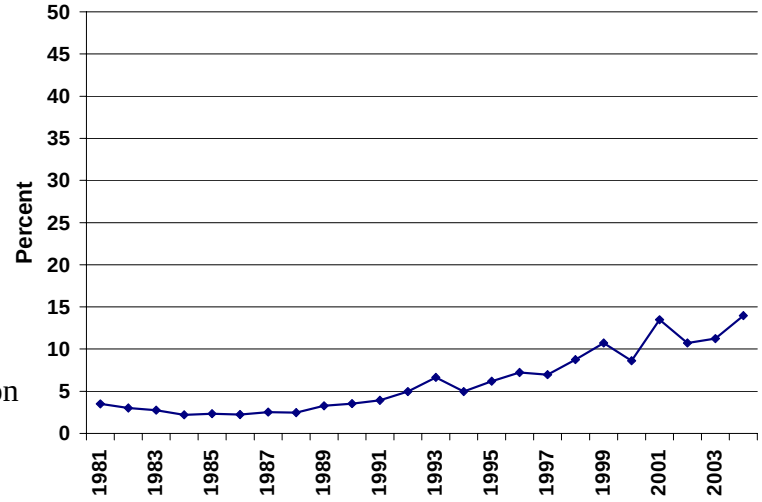


Figure 10. Percentage of the female catch bearing eggs.

II. Gulf of Maine

The percentage of culled lobsters in the Gulf of Maine was low from 1981 to 1983, increased sharply reaching a time series high of 23% in 1986, and has varied without trend near 20% since (Figure 12). The observed increase in the cull rate of lobsters in the mid-1980's corresponds with an increase in fishing effort during the same time period. This likely reflects an increase in the frequency of lobster to lobster trap interaction.

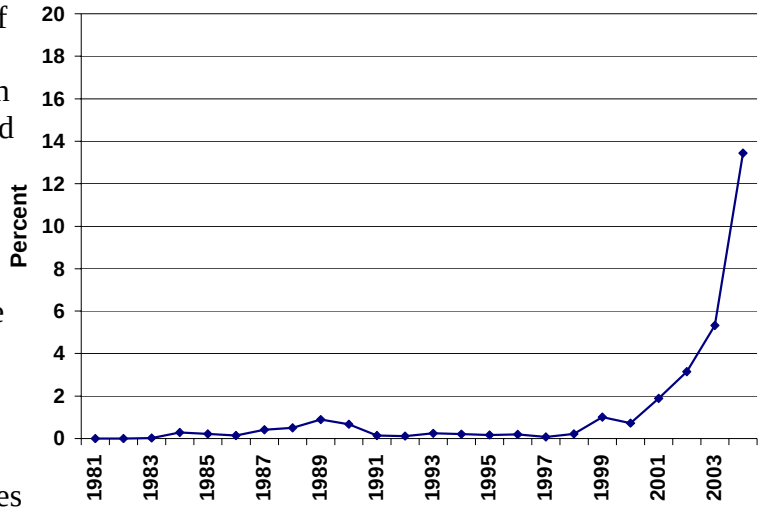


Figure 11. Percentage of the female catch with v-notches (zero-tolerance definition).

Male lobsters generally comprised less than half of the legal-sized catch with a time series average of 46.5% (Figure 13). The sex ratio of legal males has been decreasing since 1991, and has been below the time series average since 1998. In 2004, males made up only 32% of the legal-sized catch, a time series low. The sub-legal lobster catch is also comprised of generally fewer males than females. Average percent male ranged from a high in 1991 (42%) to a low in 1996 (32%), and has mostly varied around the time series average of 38.3% (Figure 13). Over the past decade, there has been a slight tendency for the percentage of males to be slightly lower than the average.

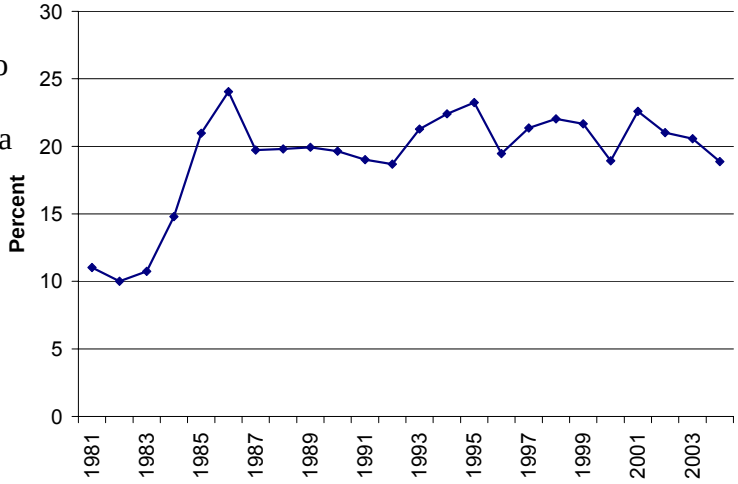


Figure 12. Percentage of total catch that were "culls".

Shell disease in the Gulf of Maine has remained relatively low since the start of monitoring in 2000 (Figure 14). Visible disease symptoms have never been observed in more than 7% of the catch. Disease incidence for the last three years has been down from a high in 2001, with no change from 2003 to 2004.

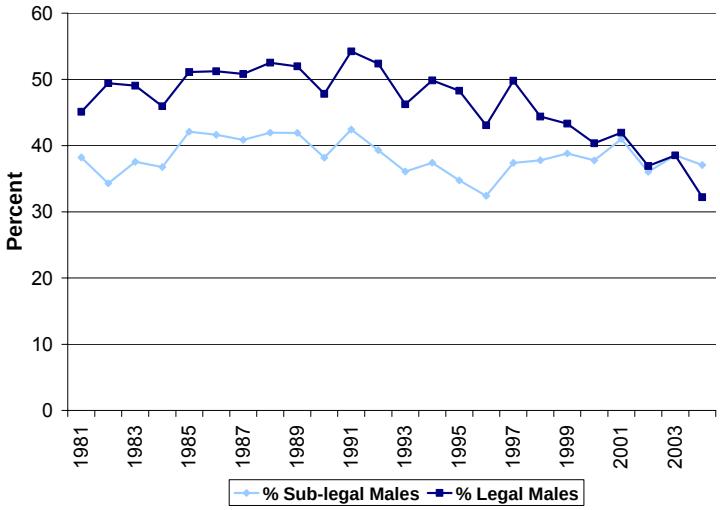


Figure 13. Percentage of the sub-legal and legal catch that was male.

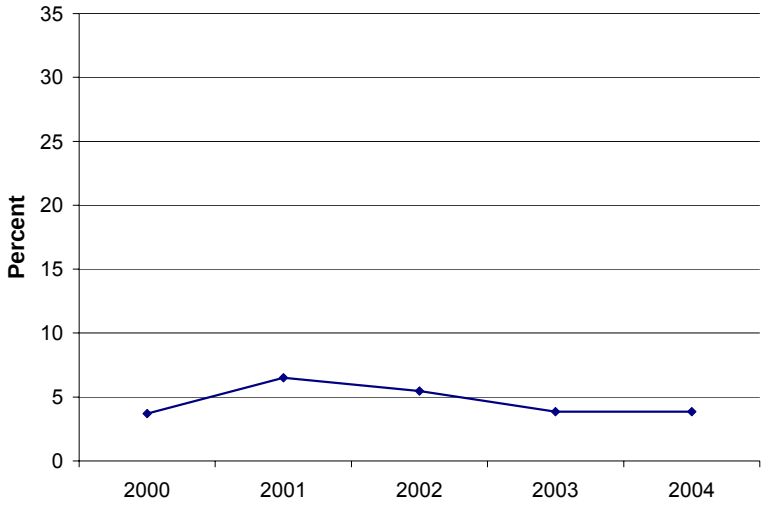


Figure 14. Percentage of total catch with shell disease.

Gulf of Maine Lobster Relative Abundance

The relative abundance of legal and sub-legal sized lobsters in GOM is depicted in Figures 15 and 16 respectively. Survey indices exhibited a high degree of inter-annual variability most likely related to annual differences in the availability of lobsters to the survey gear. Despite this variability, time series trends were discerned with the assistance of Loess smoothed trend lines.

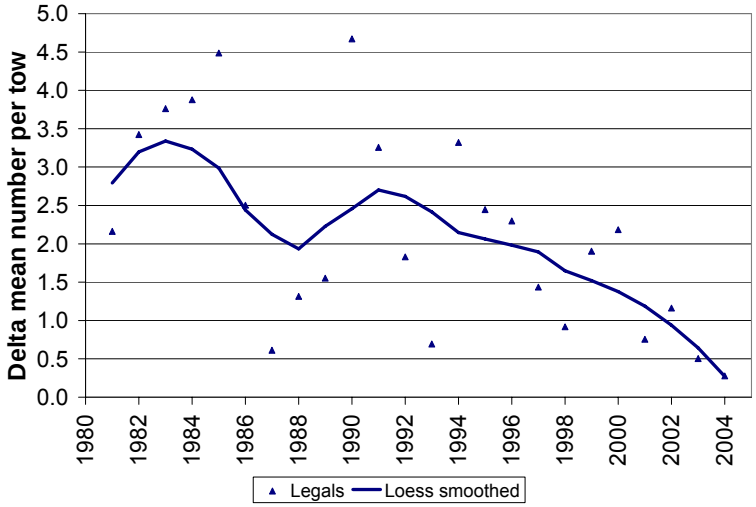


Figure 15. Delta mean number of legal lobsters per tow and the Loess smoothed curve from the Massachusetts Fall bottom trawl survey.

An average of 90% of the entire survey catch consisted of sub-legal lobsters over the course of the time series. This is expected because the sub-legal portion of the population is not subjected to commercial exploitation.

The relative abundance of legal lobsters was generally high near the beginning of the time series. The smoothed data show an overall downward trend in the relative abundance of legal lobsters over the course of the time series. This downward trend is particularly dramatic from the early 1990's until present.

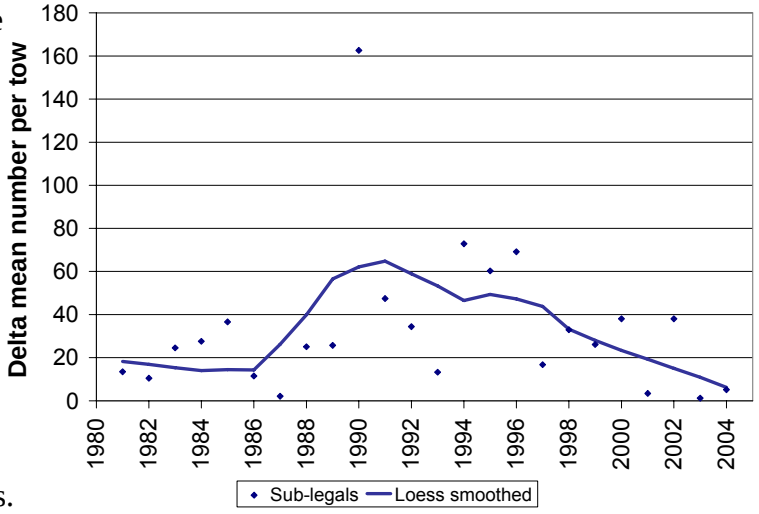


Figure 16. Delta mean number of sub-legal lobsters per tow and the Loess smoothed curve from the Massachusetts Fall bottom trawl survey.

The relative abundance trend of sub-legal sized lobsters was markedly different than that observed for legal lobsters. Relative abundance of sub-legals was low at the beginning of the time series, higher in the middle portion, and low again in recent years. Three of the past four years have had some of the lowest values since the survey began, with 2003 as the absolute low (1.2). The smoothed sub-legal data clarify the trend, showing an increase in relative abundance from the mid 1980's until the early 1990's, after which values steadily decline.

Juvenile Lobster Suction Sampling Survey

2005 Sampling Season

MarineFisheries staff sampled a total of 182 lobsters in the three Gulf of Maine suction sampling areas: Salem Sound = 86, Boston Harbor = 88, Cape Cod Bay = 8.

Time Series Trends

Since the inception of the suction sampling program in 1995, there has been an overall increase in the density of YOY and EBP lobsters at each of the three regions sampled in the Gulf of Maine (Figures 17 and 18) There has been some year-to-year variability, but no consistent trend is obvious in these fluctuations. It is possible, however, that Cape Cod Bay experiences biannual fluctuations, where almost consistently since 1995 the density has increased in one year and decreased the following year.

The highest mean YOY lobster densities recorded in Cape Cod Bay and Salem Sound were in 2004 (at 1.33 and 1.66 per m^2, respectively), while the highest recorded in Boston Harbor was in 2005 (at 0.6 per m^2) (Figure 19). Cape Cod Bay densities dropped to 0.2 per m^2 in 2005, the largest single year change in the history of sampling in Massachusetts waters (-1.11 per m^2).

Salem Sound sites consistently had the highest mean EBP density each year (Figure 18). Salem Sound generally had the highest YOY densities as well, although occasionally Cape Cod Bay experienced higher YOY densities (in 1997 and 2000). Although not depicted in these figures, sites that were suction sampled in the outer region of Boston Harbor usually had higher YOY and EBP densities than sites that were sampled in the inner Boston Harbor regions. These differences are most likely due to the drastic

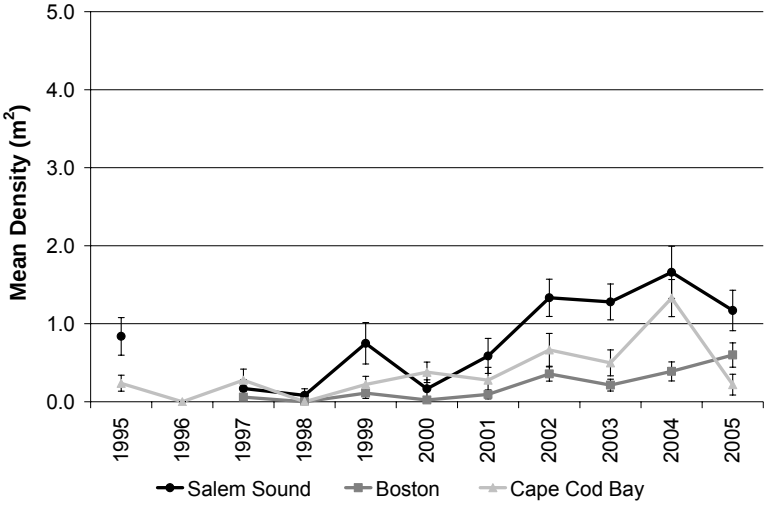


Figure 17. Mean density (± S.E.) of YOY lobsters in 3 Gulf of Maine regions.

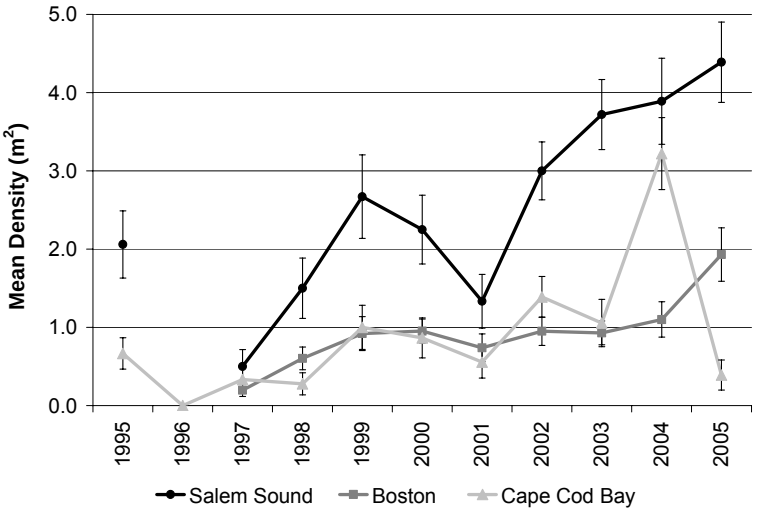
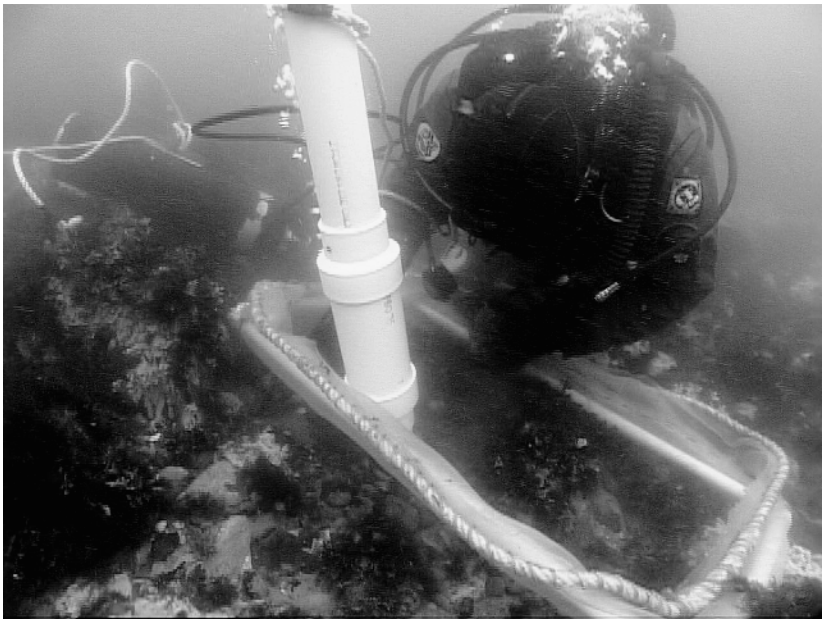


Figure 18. Mean density (± S.E.) of EBP lobsters in 3 Gulf of Maine regions.

variability in environmental conditions that Boston Harbor experiences on a daily basis. The inner harbor tends to have lower flow than the outer harbor sites. Outer sites are more directly exposed to wind and stronger water current; therefore, the larval delivery to these sites is much higher.

There are several biotic and abiotic factors which influence total EBP lobster abundance. Abiotic factors including temperature, (McKenzie 1987) wind, and water currents (Wahle and Incze 1997) are capable of having a significant effect on larval settlement. Biotic

factors such as larval supply, competition for available habitat, and predation by co-occurring decapod crustaceans or finfish can also have a significant effect on EBP lobster abundance in a given area (Barshaw and Lavalli 1988). Yearly variability of EBP lobster densities may be related to the influences of biotic and abiotic factors of that particular year.



Gulf of Maine Stock Status

The lobster stock in the Massachusetts portion of the Gulf of Maine/Lobster Management Area 1 is in poor condition.

Stock abundance as measured empirically by the *MarineFisheries* bottom trawl survey is at all time low levels. This trend is supported by modeled estimates of stock abundance for this area in the 2005 ASMFC Lobster Stock Assessment (ASMFC 2006).

Fishing mortality (F) rates for this area are extremely high (ASMFC 2006). The 2001 to 2003 average sexes combined fishing mortality rate was 1.89. This was 40% above the time series median and the second highest three year average F in the time series.

Lobster landings in GOM are very low. Four out of the five years between 2000 and 2004 are the lowest values in the time series dating back to 1981. Furthermore the commercial catch is extremely dependent on newly recruited lobsters. For the past decade the proportion of the catch within one molt of minimum legal size has hovered around 90%. This dependency on newly recruited lobsters puts the fishery at considerable risk of collapse, whereby a few years of poor recruitment would lead to drastic declines in landings.

The size distribution of lobsters in GOM is extremely truncated. This is consistent with a population that is subjected to high levels of commercial exploitation. At the current 3 ¼ " minimum legal size only about 29% of female lobsters are sexually mature (Estrella and McKiernan 1985). This in combination with high exploitation rates and relatively few large lobsters in the population to provide egg production put this stock at a high risk of recruitment failure.

While the *MarineFisheries* EBP lobster survey is not of sufficient length to be able to predict future landings to the fishery, results may provide some insight into the cause of the current stock conditions. Between 1996 and 1998 GOM experienced 3 consecutive years of very low YOY lobster settlement. If this period of low settlement is projected forward five to eight years (the average amount of time it takes for a lobster to reach minimum legal size), poor recruitment to the fishery would be expected roughly between 2001 and 2006. To date this hypothesis has been true.

The one positive factor for the GOM stock is that between 2002 and 2004 YOY settlement was at all time highs. In the absence of mitigating factors that cause an increase in natural mortality below minimum legal size, an increase in recruitment to the fishery may be expected roughly between 2007 and 2012. However, this must be interpreted cautiously because a well established relationship between settlement and recruitment to the fishery does not yet exist.

Outer Cape Cod

Fishery Statistics

In 2004, a total of 65 fishermen reported landing 726,558 pounds of lobster from 47,503 trap hauls in the Outer Cape Cod (OCC) area. These were the highest recorded landings since the beginning of the time series.

Commercial landings in OCC are depicted in Figure 19. Landings increased steadily from 1981 to 1995, when they exceeded 800,000 pounds for the first time. Since that time landings have remained above the time series mean of 550,000 pounds, and above 800,000 pounds in five out of the last ten years. The increased landings in OCC are related to an increase in stock abundance in this area.

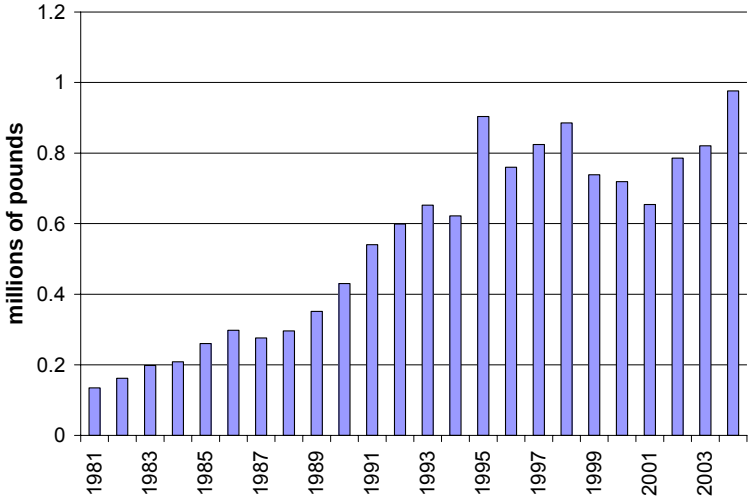


Figure 19. Commercial lobster landings in OCC.

Outer Cape Cod lobster landings accounted for 8% of the total Massachusetts lobster landings in 2004. This percentage has increased steadily since 1981, reaching all time highs in 2003 and 2004. From 1990 to 2004 the inshore (territorial) portion of OCC accounted for an average 43% of the total landings. The relative contribution of the offshore catch has increased since 1990 when it accounted for less than 40% of the total catch.

The number of active permits reporting landings between 1994 and 2004 has varied without trend around a time series mean of 70 (Table 4). The annual maximum number of traps reported fished has varied without trend around a time series mean of 25,030 traps, and the total number of trap hauls has also varied without trend around a time series mean of 44,622.

Table 4. Number of active permits reporting lobster landings, number of trap hauls, and the annual maximum number of traps fished in OCC, 1994 to 2004.

OCC	Number of Fisherman	Number of Trap Hauls	Annual Maximum Number of Traps
1994	72	42,886	22,701
1995	78	60,930	27,730
1996	64	40,367	22,597
1997	68	41,149	23,928
1998	81	54,983	30,510
1999	78	38,033	24,228
2000	74	48,360	24,458
2001	62	34,305	23,182
2002	70	38,397	26,531
2003	59	43,929	25,372
2004	65	47,503	24,095
Average	*70*	*44,622*	*25,030*

III. Outer Cape Cod

Commercial Trap Sampling

2004 Sampling Season

Lobster catch in the Outer Cape Cod region is composed of larger individuals than in other regions of the state. Ninety-one percent of the marketable catch observed in 2004 was above minimum legal size (≥85 mm CL), and ranged from 57 mm to 167 mm CL (Figure 20). A total of 3,208 individuals were sampled during the 2004 sampling season.

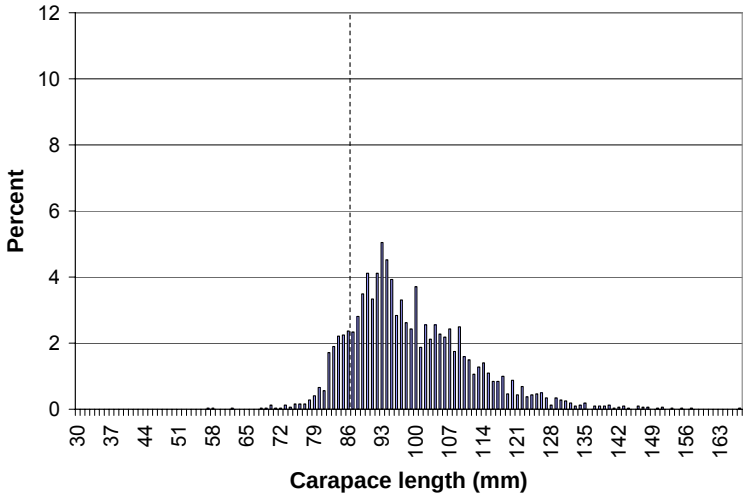


Figure 20. Percent length frequency distribution, 2004 OCC. Dashed line represents minimum legal size

Time Series Trends

From 1981 to 1993 the proportion of the catch within one molt of minimum legal size increased, reaching the time series high in 1993 (Figure 21). In the last five years, the percent of catch within one molt of minimum legal size has remained near 50%.

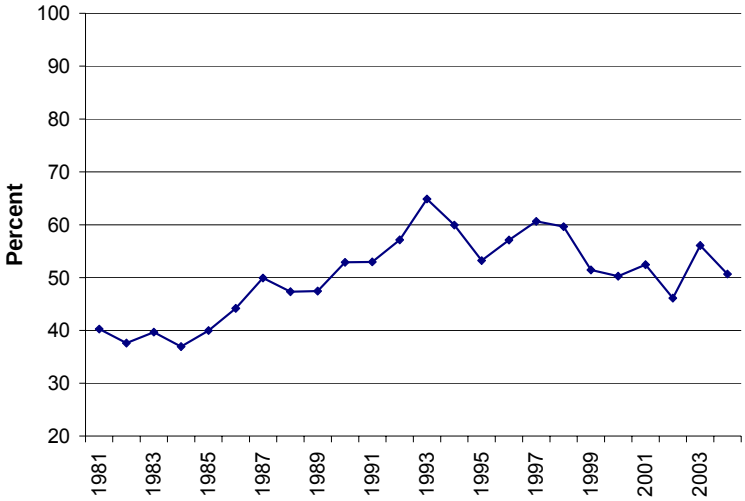


Figure 21. Percentage of the marketable catch within one molt of minimum legal size in OCC.

The percentage of the female catch bearing eggs has generally increased over the course of the time series (Figure 22). However, from the time series high in 2003 (44%), the percent ovigerous dropped dramatically (almost 16%) in 2004, the largest one year change observed since sampling began in 1981.

Outer Cape Cod follows the ASMFC definition of a v-notch (refer to methods for details). The average percentage of females v-notched increased through the 1980's to a peak in 1989 of 7%, then dropped to 0% by 1996 (Figure 23). For the past six years, the percent of females with v-notches has varied from 2% to 4%. Note that lobstermen in the Outer Cape region are not required to notch egg-bearing females.

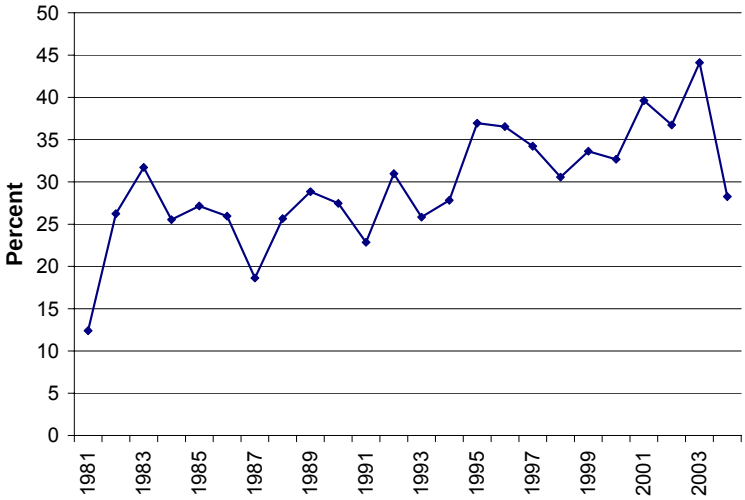


Figure 22. Percentage of the female catch bearing eggs in OCC.

The percent of culled animals observed in the Outer Cape region has increase from a low of 6% in 1981, to a high of 20% in 1995 (Figure 24). After 1995 the percentage of culls in the catch leveled

off and varied between 10 and 15 percent.

Males have generally made up an average of 36% of the legal-sized catch in the Outer Cape region, and 39% of the sub-legal catch (Figure 25). The percent of males in the legal-sized component has varied mainly between 30% to 40%, with time series lows in 1996 and 1997. The percent of males making up the sub-legal component of the catch has declined from 1982 to a time series low in 1996 (24%), after which there was a slight increase. Males have recently made up around 30% of the sub-legal catch.

The incidence of shell disease in the Outer Cape Cod region is extremely low, and has been since the start of shell disease sampling (Figure 26). Incidence peaked in 2001 at 2% of the catch.

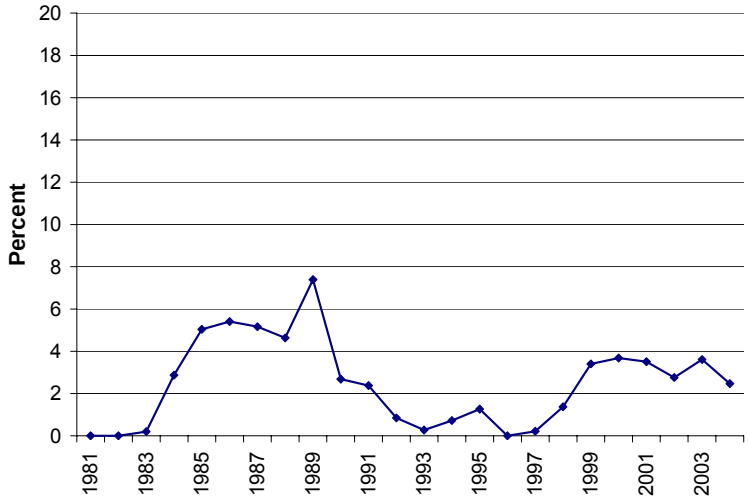


Figure 23. Percentage of the female catch with v-notches (ASMFC definition) in OCC.

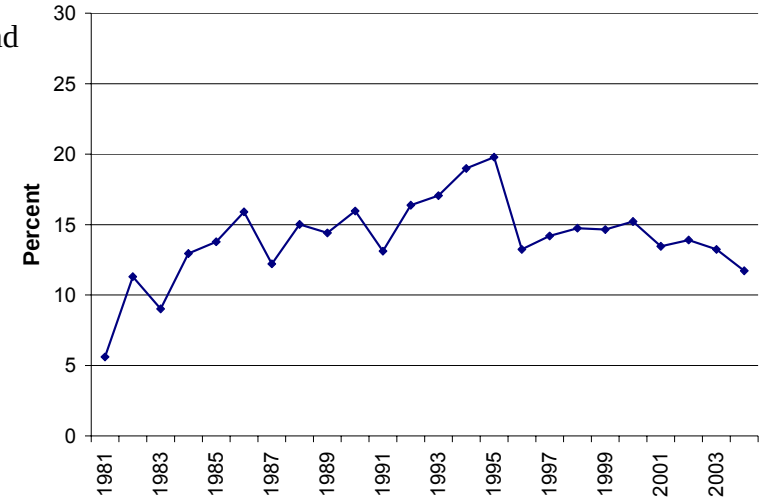


Figure 24. Percentage of total catch that were "culls" in OCC.

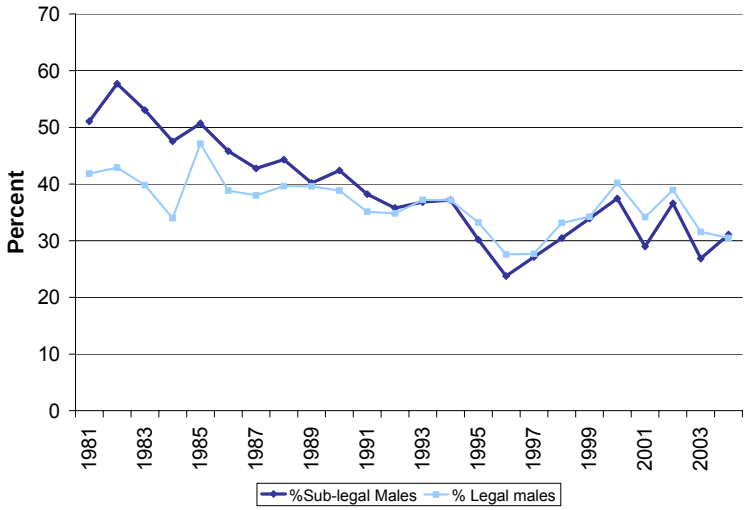


Figure 25. Percentage of the sub-legal and legal catch that was male in OCC.

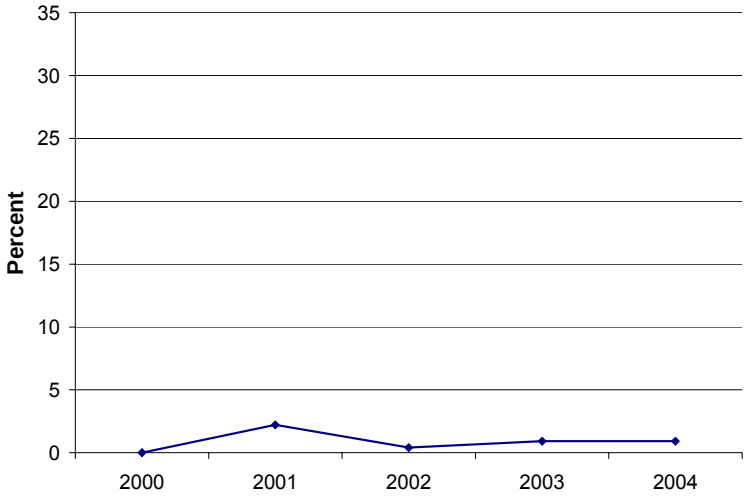


Figure 26. Percentage of total catch with shell disease in OCC

III. Outer Cape Cod

Outer Cape Cod Stock Status

The lobster stock in the Massachusetts portion of the Georges Bank Stock/Lobster Management Area OCC is in good condition.

Stock abundance is near all time high levels (ASMFC 2006). Fishing mortality rates for this area are at all time lows (SMFC 2006). The 2001 to 2003 average sexes combined fishing mortality rate was 0.29. This was 16% below the time series median and the lowest 3 year average F in the time series.

Recent lobster landings in OCC are high. Landings have remained above the 75th percentile of the time series in 6 out of the last 10 years.

The percentage of the catch within one molt of minimum legal size has been 65% or lower throughout the entire time series. This lack of dependency on newly recruited lobsters provides this fishery with a buffer against drastic declines in landings in the event of poor recruitment.

The size distribution of lobsters in OCC is robust with a broad range of size classes contributing to the population. This is consistent with a population that is subjected to low to moderate levels of commercial exploitation. At the current 3 $^{13}/_{32}$ " minimum legal size about 31% of female lobsters are sexually mature (Estrella and McKiernan 1985). Despite the relatively low proportion of sexual maturity at minimum size, the low exploitation and resulting broad size distribution ensures that total egg production for this stock is derived from many different age classes of lobsters.

Southern New England

Fishery Statistics

In 2004, a total of 149 fishermen reported landing 788,247 pounds of lobster from 224,926 trap hauls in the Massachusetts portion of Southern New England (MASNE) stock. These were the lowest recorded landings, trap hauls, and fishery participants in the time series.

Commercial landings in Massachusetts portion of SNE are depicted in Figure 27. Landings gradually increased between 1981 and 1989, then increased abruptly in 1990, when the catch exceeded two million pounds for the first time. Between 1990 and 1999 landings remained high, and reached the time series high of 2,409,451 pounds in 1997. This was followed by a drastic decline in which the catch from 2000 to 2004 accounted for 2 out of the 3 lowest values on record. The observed declines in commercial landings are related to the reduced stock abundance in SNE, recent increases in minimum size, and an increased proportion of v-notched lobsters in the catch as result of the North Cape V-Notching Program.

Commercial catch in SNE accounted for 7% of the total Massachusetts landings in 2004, and an average of 11% of the total over the course of the entire time series. From 1990 to 2004 the inshore portion (territorial waters) of MASNE accounted for an average of 27% of the total catch in this area.

The number of active permits reporting landings has gradually declined from a high of 236 in 1994 to a low of 149 permits in 2004 (Table 5). The annual maximum number of traps fished varied without trend around the time series mean of 71,699 traps between 1994 and 2002. In 2003, the number of traps fished drop substantially and reached a time series low of 53,966 in 2004. The total number of trap hauls followed a similar trend to the total number of traps fished. The recent declines in active permits and number of trap hauls represent a slight reduction in effort in the MASNE stock. This is likely the result of attrition stemming from declining stock abundance in this area.

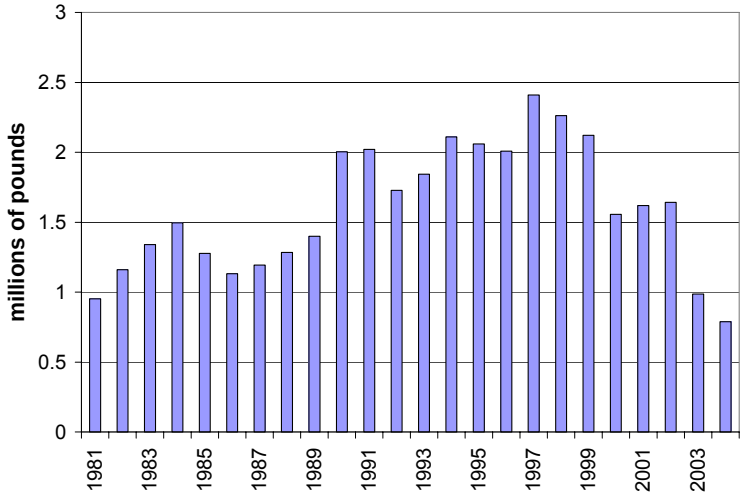


Figure 27. Commercial lobster landings in SNE.

Table 5. Number of active permits reporting lobster landings, number of trap hauls, and the annual maximum number of traps fished in SNE, 1994 to 2004.

SNE	Number of Fisherman	Number of Trap Hauls	Annual Maximum Number of Traps
1994	236	357,730	71,472
1995	222	347,442	71,269
1996	207	331,885	71,830
1997	217	389,052	76,798
1998	225	379,837	83,166
1999	224	387,418	83,474
2000	199	330,672	68,162
2001	191	332,551	66,096
2002	196	343,109	78,820
2003	171	257,650	63,634
2004	149	224,926	53,966
Average	*203*	*334,752*	*71,699*

Commercial Trap Sampling

2004 Sampling Season

MarineFisheries observed 6,361 lobsters during the 2004 sampling season in Southern New England. Lobsters observed ranged in size from 47 mm to 153 mm CL, with most falling just short of minimum legal size (86 mm CL) (Figure 28).

Time Series Trends

Since the beginning of trap sampling in 1981, more than 90% of the SNE marketable catch has been within one molt of minimum legal size (Figure 29). This value has varied around the time series mean (95%), ranging from 90% to 98%. This is indicative of a fishery dependent on new recruits.

The percent of the female catch bearing eggs has varied throughout most of the time series, between 20% to 30% (Figure 30). There were a couple of notable extremes in percent ovigerous during the early 1990's, but most of the series has remained near the mean of 25%.

Between 1981 and 1999 very few v-notched lobsters were observed in SNE. The percentage of v-notch lobsters in the catch increased slightly between 2000 and 2003, and then increased abruptly in 2004. The dramatic increase in percent of females with a v-notch in 2004 is attributable to the North Cape Lobster Restoration Project. In 2001, this project began a v-notching program to mitigate for the effects of an oil spill on lobster in Block Island Sound, R. I. in January 1996. This program expanded into Massachusetts waters in 2003 (Figure 31). There is no mandatory v-notching program in SNE.

The percentage of culled lobster observed

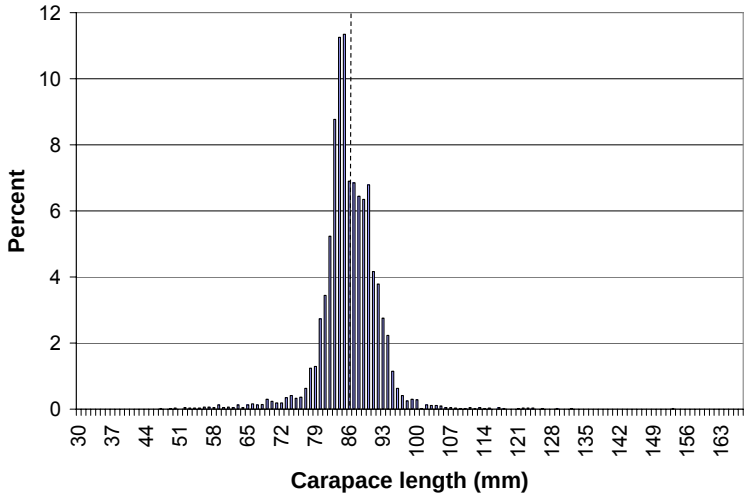


Figure 28. Percent length frequency distribution, 2004 in SNE. Dashed line represents minimum legal size.

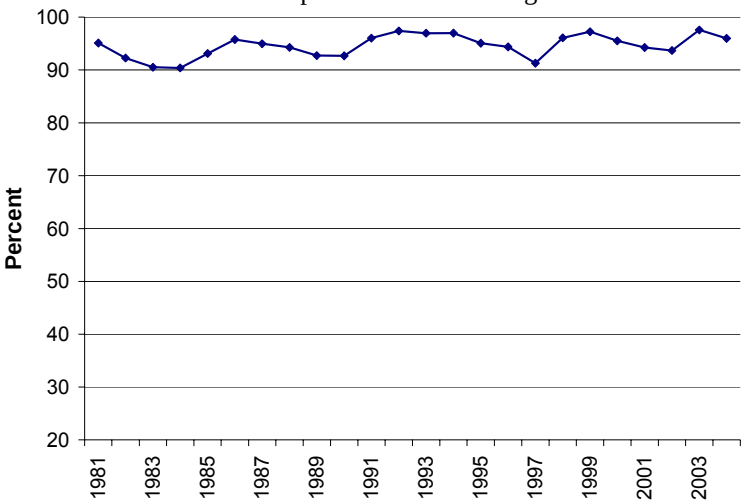


Figure 29. Percentage of the marketable catch within one molt of minimum legal size in SNE.

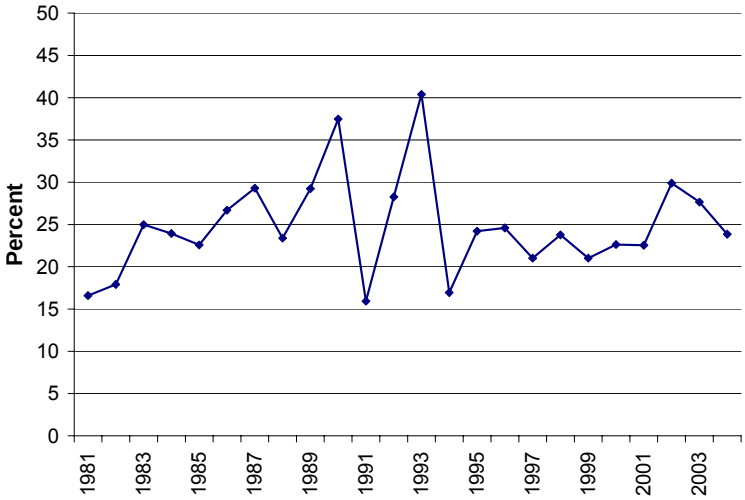


Figure 30. Percentage of the female catch bearing eggs in SNE.

was lowest early in the time series, varying between 11 and 15% until 1991 (Figure 32). A brief period of higher cull rates was then followed by percentages ranging from 14% to 18% over the last decade.

There are generally fewer males (29%) than females (71%) making up the legal sized component of the catch throughout the sampling time series (Figure 33). Four of the last five years have seen the lowest percentage of males in the legal portion of the catch since sampling began.

In the sub-legal sized catch, the percentage of males has declined over the course of the time series, with an average of 32% (Figure 33). The lowest percentages of males occurred during the six year period from 1998 to 2003, where it reached a low of 17% male. This decline in the proportion of males in the sub-legal catch could be attributable to changes the geographic distribution of sampling over time. In the late 1990's the fishery has experienced a shift to the deeper nearshore waters outside of the entrances to Buzzards Bay and Vineyard Sound. Estuarine environments, such as the upper portion of Buzzards Bay, typically have a sex ratio that is heavily skewed toward males (Watson et al 1999, Munro and Therriault 1983, Robichaud and Campbell 1991). As the fishery and subsequent sampling shifted progressively into an open ocean environment it is likely that fewer males were present in the area.

Shell disease in the Southern New England region is higher than anywhere else in Massachusetts waters. In 2003, 29% of the catch showed evidence of shell disease (Figure 34). This was followed by a large decrease (12%) in disease incidence in 2004. The prevalence of shell disease in Buzzards

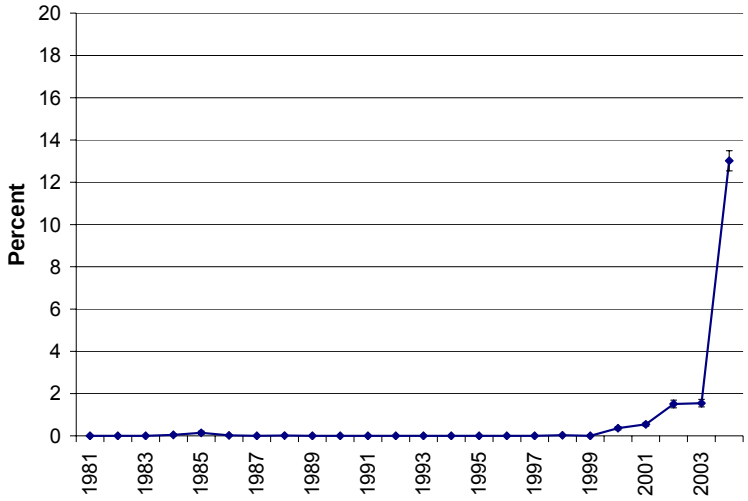


Figure 31. Percentage of the female catch with v-notches (ASMFC definition).

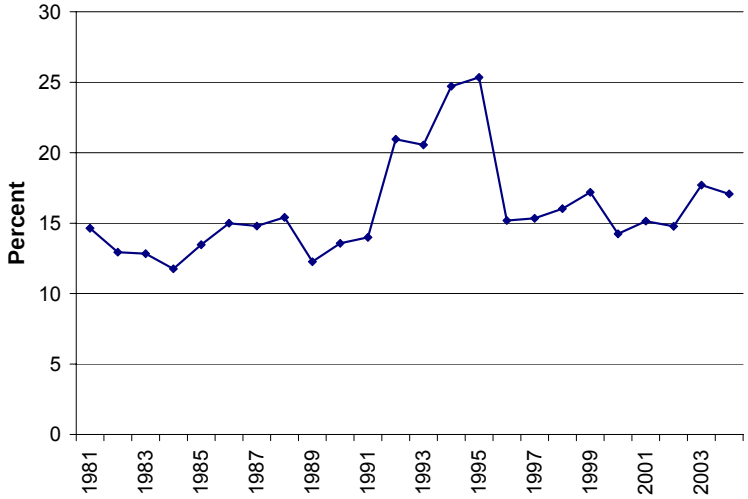


Figure 32. Percentage of total catch that were "culls" in SNE.

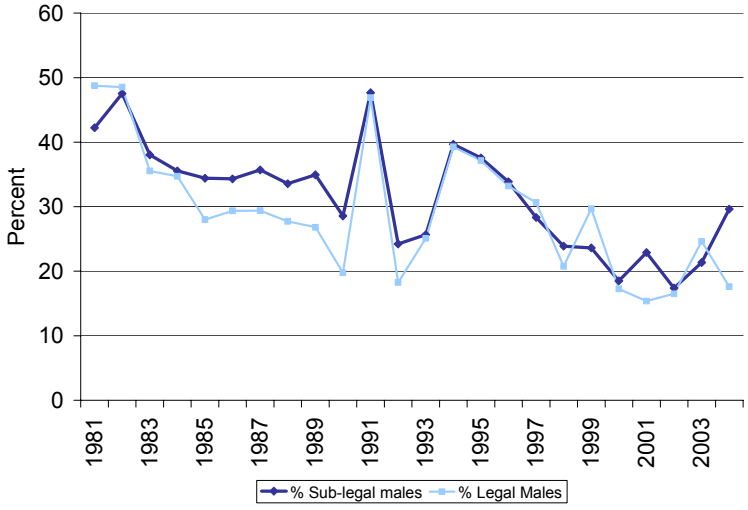


Figure 33. Percentage of the sub-legal and legal catch that was male in SNE.

Bay appears to be related to abnormally high water temperatures observed between 1998 and 2004. (Glenn and Pugh 2005).

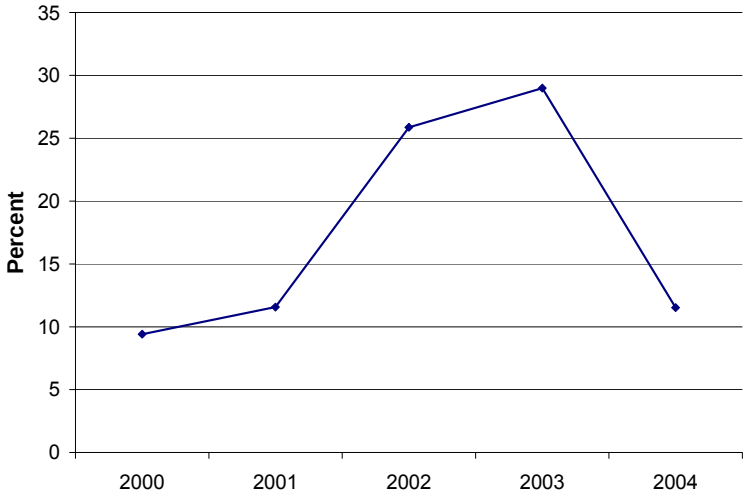


Figure 34. Percentage of total catch with shell disease in SNE.

Southern New England Lobster Relative Abundance Assessment

The relative abundance of legal and sub-legal sized lobsters in SNE is depicted in Figures 35 and 36 respectively. Survey indices exhibited a high degree of inter-annual variability most likely related to annual differences in the availability of lobsters to the survey gear. Despite this variability, time series trends were discerned with the assistance of Loess smoothed trend lines.

An average of 85% of the entire survey catch consisted of sub-legal lobsters over the course of the time series. This is expected because the sub-legal portion of the population is not subjected to commercial exploitation.

The relative abundance of legal lobsters peaked during the period of 1989 through 1993. The smoothed data exhibit a sharp increase in abundance between 1981 and 1992, when legal abundance reached a time series high. This was followed by an equally dramatic rapid decline. Abundance since 2000 has remained below the time series mean of 0.07, and has varied alarmingly close to 0 for the past decade, with 0 values recorded in 1999, 2002 and 2003. It should be noted that prior to the increase in abundance in the early 1990's, relative abundance was recorded as 0.0 for several years.

Sub-legal lobster abundance shows a similar trend. After a peak during the early 1990's, relative abundance has averaged 0.22 for the last decade (1995-2004). The last three years have had the lowest values in the history of the time series, at or near zero.

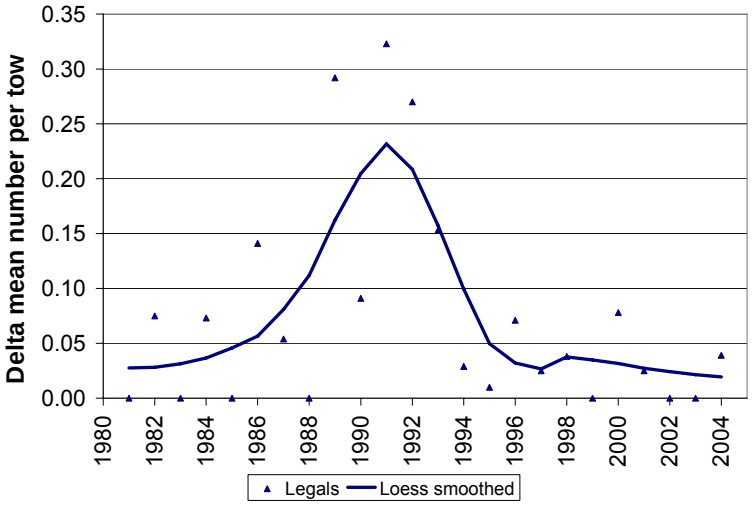


Figure 35. Delta mean number of legal lobsters per tow and the Loess smoothed curve.

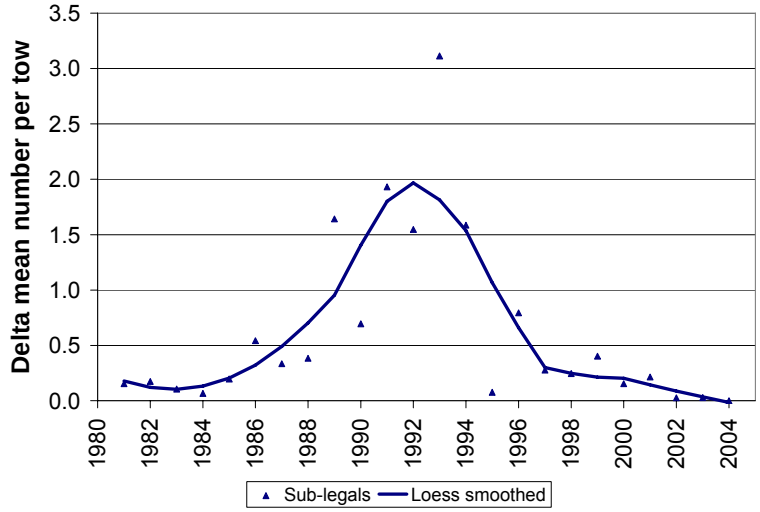


Figure 36. Delta mean number of sub-legal lobsters per tow and the Loess smoothed curve.

Juvenile Lobster Suction Sampling Survey

2005 Sampling Season

MarineFisheries staff sampled a total of seven lobsters in the Buzzards Bay region across five sites in 2005. Of these seven lobsters, four were YOY lobsters and three were EBP lobsters. No lobster >40mm were recorded this year. The Buzzards Bay region historically has much lower EBP lobster densities in comparison to areas in the Gulf of Maine region.

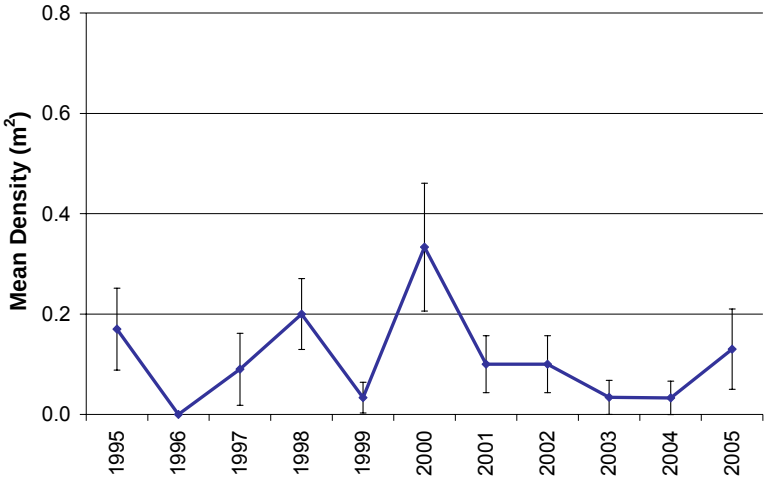


Figure 37. Density of YOY lobsters in Buzzards Bay

Time Series Trends

Since the inception of the suction sampling program in 1995, observed densities of EBP and YOY lobsters in Buzzards Bay have remained extremely low (<1 per m^2) and variable. Mean YOY lobster densities were recorded at their highest level in Buzzards Bay in 2000 (at 0.33 per m^2) and lowest in 1996 at 0 per m^2, and have otherwise varied without trend (Figure 37). The highest mean EBP lobster densities recorded in Buzzards Bay were in 1998 (at 0.63 per m^2), while the lowest was recorded in 1996 (at 0 per m^2) (Figure 38). The only remarkable trend in the data is a general decline in EBP densities from 1998 to 2003.

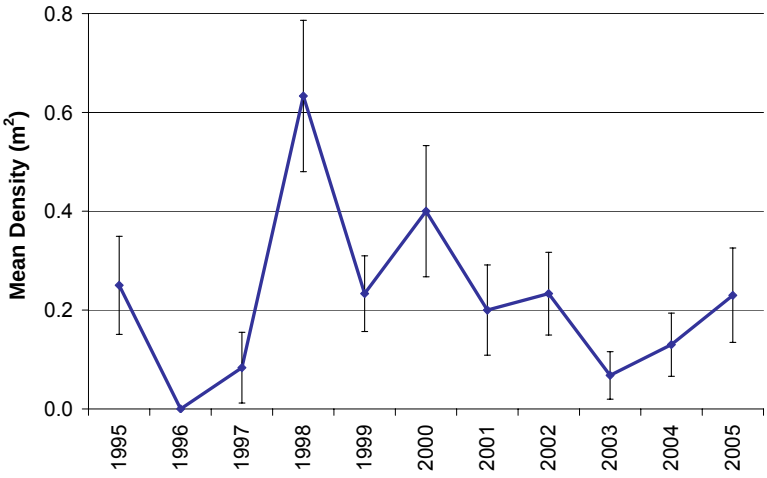


Figure 38. Density of EBP lobsters in Buzzards Bay.

There are several biotic and abiotic factors which influence total EBP lobster abundance. Abiotic factors including temperature, (McKenzie 1987) wind, and water currents (Wahle and Incze 1997) are capable of having a significant effect on larval settlement. Biotic factors such as larval supply, competition for available habitat, and predation by co-occurring decapod crustaceans or finfish can also have a significant effect on EBP lobster abundance in a given area (Barshaw and Lavalli 1988). Any of these factors may influence the density of juvenile lobsters to varying degrees from year to year.

Southern New England Stock Status

The lobster stock in the Massachusetts portion of the Southern New England/Area 2 is in poor condition.

Stock abundance as measured empirically by the *MarineFisheries* bottom trawl survey is at all time low levels. The period from 2002 through 2004 marks the three lowest levels of total lobster abundance since the inception of the survey. This trend is supported by modeled estimates of stock abundance for this area in the 2005 ASMFC Lobster Stock Assessment (ASMFC 2006).

Fishing mortality rates for this area are extremely high (ASMFC 2006). The 2001 to 2003 average sexes combined fishing mortality rate was 0.92. This represents a decline from highs observed in the late 1990's, however this is still above the time series median.

Lobster landings in SNE are very low. The catch from 2000 to 2004 accounted for 2 out of the 3 lowest values on record. Furthermore the commercial catch is extremely dependent on newly recruited lobsters. The proportion of the catch within molt of minimum legal size has exceeded 90% since the beginning of the time series. This dependency on newly recruited lobsters puts the fishery at considerable risk of collapse, whereby a few years of poor recruitment would lead to drastic declines in landings.

The size distribution of lobsters in SNE is extremely truncated. This is consistent with a population that is subjected to high levels of commercial exploitation. At the current $3\ ^{3}/_{8}$ " minimum legal size about 91% of female lobsters are sexually mature (Estrella and McKiernan 1985). The large contribution of egg production from lobsters below minimum size greatly reduces the risk of recruitment failure in this stock. However, settlement densities of YOY lobsters in SNE have consistently been low since the inception of monitoring in 1995. There are two possible hypotheses to explain this apparent contradiction. First, egg production may be limited because of low stock abundance. Second there could be a disconnect between egg production and local settlement due to environmental factors.

Since 1998 this stock has experienced an outbreak of shell disease. Between 2000 and 2004 as much as 29% of the total catch had some level of shell disease symptoms. The impact to the stock from shell disease in terms of an increase in natural mortality is not known. However, it is safe to assume that the net impacts to this stock, relative to the energetic requirements to fight the infection, are negative.

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