ASSESSMENT REPORT

FOR

GULF OF MAINE NORTHERN SHRIMP – 2011

Prepared

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by the

Atlantic States Marine Fisheries Commission's

Northern Shrimp Technical Committee

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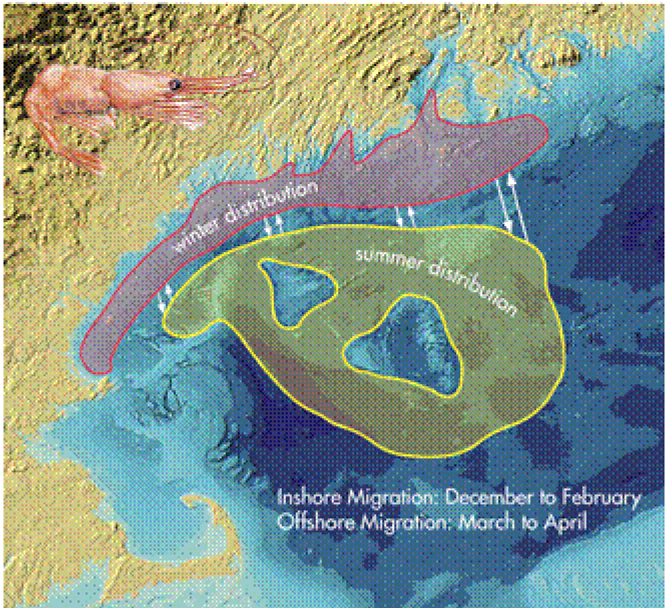
INTRODUCTION

Biological Characteristics

Northern shrimp (*Pandalus borealis* Krøyer) are hermaphroditic, maturing first as males at about 2½ years of age and then transforming to females at about 3½ years of age in the Gulf of Maine.



Distribution of adult female northern shrimp (NAMA, 2006)

Spawning takes place in offshore waters beginning in late July. By early fall, most adult females extrude their eggs onto the abdomen. Egg-bearing females move inshore in late autumn and winter, where the eggs hatch. Juveniles remain in coastal waters for a year or more before migrating to deeper offshore waters, where they mature as males. The exact extent and location of these migrations is variable and unpredictable. The males pass through a series of transitional stages before maturing as females. Some females may survive to repeat the spawning process in succeeding years. The females are the individuals targeted in the Gulf of Maine fishery. Natural mortality seems to be most pronounced immediately following hatching, and it is believed that most northern shrimp do not live past age 5 in the Gulf of Maine (reviewed by Clark et al 2000).

Fishery Management

The Gulf of Maine fishery for northern shrimp is managed through interstate agreement between the states of Maine, New Hampshire and Massachusetts. The management framework evolved during 1972-1979 under the auspices of the State/Federal Fisheries Management Program. In 1980, this program was restructured as the Interstate Fisheries Management Program (ISFMP) of the Atlantic States Marine Fisheries Commission (ASMFC). The Fishery Management Plan (FMP) for Northern Shrimp was first approved under the ISFMP in October 1986 (McInnes, 1986, FMR No. 9). Amendment 1, implemented in 2004, established biological reference points for the first time in the shrimp fishery and expanded the tools available to manage the fishery (ASMFC, FMR No. 42). Management of northern shrimp under Amendment 1 resulted in a rebuilt stock and increased fishing opportunities. However, early season closures occurred in the 2009/2010 and 2010/2011 fishing seasons because landing rates were far greater than anticipated. Furthermore, untimely reporting resulted in short notice of the season closures and an overharvest of the recommended total allowable catch (TAC) by 28% in 2010 and 48% in 2011. In response to these issues, Amendment 2, approved by the ASMFC Northern Shrimp Section (hereafter, Section) in October 2011, provides management options to slow catch rates throughout the season, including trip limits, trap limits, and days out of the fishery.

Amendment 2 completely replaces the FMP, and modifies the fishing mortality reference points to include a threshold level, includes a more timely and comprehensive reporting system, and allows for the initiation of a limited entry program to be pursued through the adaptive management addendum process. Any new tools proposed to manage the shrimp fishery must be implemented through the ASMFC addendum process.

Within the ISFMP structure, the Northern Shrimp Technical Committee (NSTC) provides annual stock assessments and related information to the Section. Annually, the Section decides on management regimes after thorough consideration of the NSTC stock assessment, input from the Northern Shrimp Advisory Panel, and comment from others knowledgeable about the shrimp fishing industry.

At its fall 2010 meeting, the Section approved a 136-day season: December 1, 2010, through April 15, 2011, inclusive. This will be referred to as the “2011 season” throughout this document. In addition, it continued to require the use of a finfish excluder device known as the "Nordmore Grate" throughout the shrimp fishing season. The Section also maintained the requirement that made it unlawful to use mechanical “shaking” devices to cull, grade, or separate catches of shrimp.

The Section took emergency action to close the northern shrimp fishery on February 28, 2011. The decision to close the fishery prior to the season end of April 15th was based on preliminary landings data that indicated that harvest was already at 4,192 metric tons, 192 metric tons in excess of the NSTC recommended landings level. The NSTC projected that landings could total 7,000 metric tons if harvest continued through April 15.

Fishery Assessment

Stock assessments conducted since the 1980's have identified strong year classes (e.g., those hatched in 1982, 1987, 1992, 2001, 2004). Each strong year class supports the shrimp fishery for about three years commencing about three years after hatching.

In its 2010 assessment, the NSTC estimated the current exploitable biomass of shrimp to be above the average for the 1984-2010 time series, and recommended the Section set a 2011 season that would result in landings of no more than 3,800 to 4,200 metric tons (mt), depending on the size of the individual shrimp, in order to maintain a fishing mortality rate (F) of no more than 0.29, in accordance with the FMP target.

The following report presents the results of the Technical Committee's 2011 stock assessment. Analyses and recommendations are based on: 1) research vessel survey data collected by the NSTC during the annual summer shrimp survey, by the Northeast Fisheries Science Center (NEFSC) during the fall trawl survey, by the state of Maine during 1968-1983, and by the Maine-New Hampshire spring inshore trawl survey; 2) commercial landings data collected by the National Marine Fisheries Service (NMFS) during 1968-2000; 3) biological sampling of the commercial landings by personnel from the participating states and the NMFS; and 4) data from federal and Maine vessel trip reports (VTRs) filed by shrimp fishers since 2001. In addition to index methods of assessing the stock (e.g. trends in landings data, commercial effort and CPUE estimates, indices of abundance), population models including Collie-Sissenwine Analysis, ASPIC biomass dynamics, yield per recruit, and eggs per recruit models are used to provide guidance for management of the stock.

Status of the Stock

The current fishing mortality reference points as established by Amendment 2 and re-estimated by the NSTC in 2011 are F_{target} =0.32, $F_{threshold}$= 0.41, and F_{limit}= 0.60. The terminal year estimate of fishing mortality from the base run of the stock assessment is F_{2011}= 0.68, indicating that fishing mortality has exceeded the threshold, resulting in overfishing. The current biomass reference points as established by Amendment 2 are $B_{threshold}$ = 9,000 mt and B_{limit} = 6,000 mt. The terminal year estimate of biomass is 6,500 mt, indicating that the biomass is below the threshold, resulting in an overfished condition. Amendment 2 states that if fishing mortality exceeds the limit level, and biomass is less than the threshold level, the Section must act immediately to reduce fishing mortality.

COMMERCIAL FISHERY TRENDS

The NSTC recently reviewed state and federal harvester reports (vessel trip reports (VTRs)) for the 2001 through 2011 fishing seasons, and updated the landings, trips, and boat data in Tables 1-6 and associated figures for those years.

Landings

Annual landings of Gulf of Maine northern shrimp declined from an average of 11,400 metric tons (mt) during 1969-1972 to about 400 mt in 1977, culminating in a closure of the fishery in 1978 (Table 1). The fishery reopened in 1979 and landings increased steadily to over 5,000 mt by 1987. Landings ranged from 2,300 to 4,400 mt during 1988-1994, and then rose dramatically to 9,500 mt in 1996, the highest since 1973. Landings declined to an average of 1,900 mt for 1999 to 2001, and dropped further in the 25-day 2002 season to 450 mt, the lowest northern shrimp landings since the fishery was closed in 1978. Landings then increased steadily, averaging 2,100 mt during the 2003 to 2006 seasons, then jumping to 4,900 mt in 2007 and 5,000 mt in 2008. In 2009, 2,500 mt were landed during a season that was market-limited. The proposed 180-day season for 2010 was cut short to 156 days due to the industry exceeding the committee's recommended landings cap for that year, and concerns about small shrimp. The preliminary landings for 2010 are 6,256 mt, which is more than double the landings observed in 2009, and well above the recommended limit of 4,900 mt.

As in 2010, the 2011 season was closed early. The season was scheduled to be 136 days, considerably shorter than the proposed 180-day season of 2010. On February 28, after emergency action by the Section, the 2011 season was closed due to harvest above the recommended limit, completing a 90-day season. A preliminary total of 5,940 mt of shrimp were landed, exceeding the recommended limit (4,000 mt) by approximately 2,000 mt (Table 1 and Figure 1). The average price per pound was $0.75 and the preliminary estimated landed value of the catch was $9.8 million (Table 1). Based on late reporting rates for the past five years, the NSTC anticipates about 10% of harvester reports for the 2011 season had not yet been received, as of September, 2011 when data for this report were compiled.

Maine landed 86% (5,118 mt) of the 2011 season total, New Hampshire followed with 11% (631 mt) and Massachusetts landed 3% (195 mt) of the season total (preliminary data, Table 1). The proportional distribution of landings among the states was similar to 2003-2010, but has shifted gradually since the 1980's when Massachusetts accounted for about 30% of the catch (Table 1 and Figure 1).

The relative proportion of landings by month in 2011 (Table 2 and Figure 2a, preliminary data) remained generally similar to past years, except for an increase in December 2010 landings. The month of January 2011 (31 open days) yielded the highest proportion of the catch (47%) with February slightly lower (40%) and December (14%) yielding the lowest. Compared to previous years, December had a higher than normal percentage, possibly due to the shrimp migrating inshore earlier than usual.

Most northern shrimp fishing in the Gulf of Maine is conducted by otter trawls, although traps are also employed off the central Maine coast. According to federal and state of Maine VTRs, trappers averaged 12% of Maine's landings during 2001 to 2007, 18% during 2008 to 2010 (preliminary data), and 15% (preliminary data) in 2011 (Table 3). Trapping effort has been increasing in recent years, accounting for 21% of Maine's landings in 2010, but may have been lower relative to trawling in 2011 because the early closure of the season may have impacted trappers more than trawlers.

Size, Sex, and Maturity Stage Composition of Landings

Size composition data (Figures 3-5) collected from catches since the early 1980s indicate that trends in landings have been determined primarily by recruitment of strong (dominant) year classes. Landings more than tripled with recruitment of a strong assumed 1982 year class in 1985 – 1987 and then declined sharply in 1988. A strong 1987 year class was a major contributor to the 1990-1992 fisheries. A strong 1992 year class, supplemented by a moderate 1993 year class, partially supported large annual landings in 1995 – 1998. Low landings in 1999 – 2003 were due in part to poor 1994, 1995, 1997, 1998, and 2000 year classes with only moderate 1996 and 1999 year classes. A very strong 2001 year class supported higher landings in 2004 – 2006. In the 2007 fishery, landings mostly comprised assumed 4 year-old females from the moderate to strong 2003 year class, and possibly 6 year-olds from the 2001 year class. 2008 landings were mostly composed of the assumed 4 year-old females from the strong 2004 year class, and the 2003 year class (assumed 5 year–old females, which first appeared as a moderate year class in the 2004 survey). In the 2009 fishery, catches were comprised mainly of assumed 5-year old females from the strong 2004 year class. Catches in the 2010 fishery consisted of assumed 5 year-old females from the 2005 year class and possibly some 4-year-old females from the weak 2006 year class. The 2011 fishery consisted mainly of 4-year-old females from the assumed 2007 year class. Numbers of 5-year-old shrimp were limited this year likely due to the weak 2006 year class. Transitionals and female I's from the 2008 year class, and some males and juveniles from the assumed 2009 year class were observed, especially in the Massachusetts and New Hampshire catches and Maine's December and January trawl catches (Figures 3-5).

Maine trappers landed fewer small shrimp, and generally were more apt to catch females after egg hatch, than trawlers, as in previous years (Figure 3). See the table below for the average counts per pound by month and gear. Average counts per pound were higher in 2011 than they were in 2010 and confirm that the 2011 fishery consisted of mostly assumed 4-year-olds compared to mostly 5-year-olds in the 2010 fishery.

Mean counts of all shrimp species per pound of landings, from port samples:

2010 Mean Counts per Pound, all shrimp species	Dec.	Jan.	Feb.	Mar.	Apr.	May
Maine Trawls	41	41	38	39	55	53
Maine Traps	n/a	37	34	34	n/a	n/a
Massachusetts	n/a	53	52	n/a	n/a	n/a
New Hampshire	41	45	47	n/a	51	n/a

n/a=no samples

2011 Mean Counts per Pound, all shrimp species	Dec.	Jan.	Feb.
Maine Trawls	49	47	45
Maine Traps	n/a	40	39
Massachusetts	53	54	59
New Hampshire	50	50	48

Spatial and temporal differences in the timing of egg-hatch can be estimated by noting the relative abundance of ovigerous females to females that have borne eggs in the past but are no longer carrying them (female stage II). According to port samples for the 2011 season, in December, in Maine, 5% of the trawled catch was female stage II; in January this increased to 10% and in February it increased to 40%. These percentages are higher than in recent seasons, suggesting that egg hatch in the 2011 season was somewhat earlier than in 2008 and 2009. Egg hatch was earlier in 2010 as well.

In New Hampshire and Massachusetts trawl catch samples combined, the percentage of female stage II shrimp for the 2011 season was 13% in December, 16% in January, and 43% in February (Figure 4), all higher than Maine for the same months, probably reflecting the eastern Gulf lagging the west in the timing of egg hatch.

Discards

Port samplers in Maine reported seeing manual shakers on a few trawl vessels during April 2010, but made no similar observations in 2011. Maine trappers also manually pick or shake out small northern shrimp, and the smaller Pandalid species of veined or striped shrimp (*Pandalus* *montagui* and *Dichelopandalus leptocerus*) on occasion. Because of a lack of detailed information, shrimp discards from the shrimp and other fisheries are not evaluated in this assessment.

Black Gill Syndrome

Shrimp collected during routine port-sampling in Maine in 2003 exhibited a high incidence (greater than 70%) of Black Gill Syndrome, also called Black Gill Disease or Black Spot Syndrome. Affected shrimp displayed melanized, or blackened gills, with inflammation, necrosis, and significant loss of gill filaments. Black Gill Syndrome has also been documented in white shrimp in South Carolina (http://praise.manoa.hawaii.edu/news/eh216.html) and in the Gulf of Maine in the 1960s and 1970s (Apollonio and Dunton, 1969; Rinaldo and Yevitch, 1974). Its etiology is unknown, although fungal and ciliated protist parasites have been implicated. In samples collected in Maine during the 2004-2011 fisheries, the incidence of Black Gill Syndrome was much lower, and detected cases were much less severe, than in 2003.

Effort and Distribution of Effort

Since the 1970's, effort in the fishery (measured by numbers of trips in which shrimp gear is used) has increased and then declined on several occasions. In the 1980’s there was a gradual increase in the total number of trawl trips (Table 4 and Figure 6a) to a peak of 12,285 during the 1987 season. Increases in season length, shrimp abundance, and record ex-vessel prices, coupled with reduced abundance of groundfish, all contributed to this increase. Effort subsequently fell to 5,990 trips in the 1994 season. Effort nearly doubled between 1994 and 1996 and then declined again from the 1996 level of 11,791 to 1,034 trips in 2002, a year with only a 25-day open season. The number of trips increased during 2003-2005 as the seasons were lengthened, to 3,017 trawl trips in 2005. Trips in 2006 dropped to 1,726, likely due to poor market conditions, increased in 2007 to 3,096, and increased in 2008 to 3,995, the most since 1999. In 2009, the length of the season was increased to 180 days while the effort decreased to 2,096 trips, likely caused by limited demand from the processors and poor market conditions (Table 4). In what turned out to be a 156-day season in 2010, effort increased dramatically to 4,081 trips (preliminary data). The market conditions were improved from prior years due to Canada’s limited supply and an increase in local markets. In 2011, the truncated 90-day season yielded an effort similar to 2010 with 4,711 trips (Table 4). The high level of effort was again due in part to a limited supply in Canada and demand from local markets.

The number of vessels participating in the fishery in recent years has varied from a high of 347 in 1996 to a low of 144 in 2006 (Table 6). In 2011, there were 276 vessels from Maine, 12 from Massachusetts, and 20 from New Hampshire, for a total of 308, according to federal VTR and Maine harvester logbook data (preliminary). Of the 276 vessels from Maine, 125 were trapping.

Prior to 1994, effort (numbers of trips by state and month) was estimated from landings data collected from dealers, and landings per trip information (LPUE) from dockside interviews of vessel captains: $Effort = \frac{Landings}{LPUE}$

Beginning in the spring of 1994, a vessel trip reporting system (VTR) supplemented the collection of effort information from interviews. From 1995 to 2000, landings per trip (LPUE) from these logbooks were expanded to total landings from the dealer weighouts to estimate the total trips: $$Total.Trips = VTR.Trips \frac{Total.Landings}{VTR.Landings}$$

Since 2000, VTR landings have exceeded dealer weighout landings, and the above expansion is not necessary. However, VTRs for 2010 and 2011 are still being received and processed. Therefore, landings and effort estimates reported here for recent years should be considered extremely preliminary. The 1996 assessment report (Schick et al. 1996) provides a comparison of 1995 shrimp catch and effort data from both the NEFSC interview and logbook systems and addresses the differences between the systems at that time. It showed a slightly larger estimate from the logbook system than from the interview system. Thus effort statistics reported through 1994 are not directly comparable to those collected after 1994. However, patterns in effort can be examined if the difference between the systems is taken into account. An additional complication of the logbook system is that one portion of the shrimp fishery may not be adequately represented by the logbook system during 1994-1999. Smaller vessels fishing exclusively in Maine coastal waters are not required to have federal groundfish permits and were not required to submit shrimp vessel trip reports until 2000. In the 1994-2000 assessments, effort from unpermitted vessels was characterized by catch per unit effort of permitted vessels.

Seasonal trends in distribution of trawl effort can be evaluated from port interview data. The relative magnitude of offshore fishing effort (deeper than 55 fathoms) has varied, reflecting seasonal movements of mature females (inshore in early winter and offshore following larval hatching), but also reflecting harvesters' choices for fishing on concentrations of shrimp. Of the 176 interviews of Maine trawl fishermen in 2011, 87% fished inshore and 13% fished offshore. The highest proportion of inshore trips from 153 interviews occurred in January (51%), followed by February (45%), and in December comprised 4% of the trips. Of the offshore trips, 74% were in December, decreasing to about 17% in January and 9% in February based on a total of 23 harvesters reporting offshore trips during port interviews.

Locations of 2011 fishing trips and landings from federal and state VTRs are plotted by 10-minute square in Figure 7.

Catch per Unit Effort

Catch per unit effort (CPUE) indices have been developed from NMFS interview data (1983-1994), logbook data (1995-2011), and Maine port interview data (1991-2011) and are measures of resource abundance and availability (Table 7 and Figure 6b). They are typically measured in catch per hour (from Maine interview data) or catch per trip. A trip is a less precise measure of effort, because trips from interviews and logbooks include both single day trips and multiple day trips (in the spring), and the proportion of such trips can vary from season to season. Also, in some years, buyers imposed trip limits on their boats.

Pounds landed per trawl trip, from VTRs, averaged 1,393 pounds during 1995-2000. In 2001, the catch per trip dropped to 752 pounds, the lowest since 1988, and remained low, at 857 pounds, in 2002. During 2003 – 2005 it averaged 1,576 lbs/trip. The increasing trend continued in 2006 with 2,616 pounds per trip. In 2007, the highest pounds per trip of the time series was observed at 3,129 pounds. It decreased in 2008 and again in 2009 to 2,231 pounds per trip (preliminary); still well above average. The pounds per trip increased in 2010 to 2,727, which is the second highest in the time series. There was a slight decrease in 2011 to 2,422 pounds per trip (preliminary, Figure 6b).

More precise CPUE indices (pounds landed per hour trawling) have also been developed for both inshore (depth less than 55 fathoms) and offshore (depth more than 55 fathoms) areas using information collected by Maine's port sampling program, and agree well with the (less precise) catch per trip data from logbooks (see Table 7 and Figure 6b). Maine's inshore trawl CPUE for 2011 was 334 lbs/hr, offshore was 435 lbs/hr, and the season average was 347 lbs/hr, well above the time series average of 249 lbs/hr (Table 7). It is notable that the highest monthly average CPUE observed for Maine was during December (425 lbs/hr), followed by January (353 lbs/hr) and then February (315 lbs/hr). This is an unusual pattern – during the past decade, the highest CPUEs have usually been observed in February (White and Lash, 2011).

RESOURCE CONDITIONS

Trends in abundance of Gulf of Maine northern shrimp have been monitored since the late 1960's from data collected in Northeast Fisheries Science Center (NEFSC) spring and autumn bottom trawl surveys and in summer surveys by the State of Maine (discontinued in 1983). A Maine-New Hampshire inshore trawl survey has been conducted each spring and fall, beginning in the fall of 2000 (Sherman et al. 2005). A state-federal survey was initiated by the NSTC in 1984 to specifically assess the shrimp resource in the western Gulf of Maine. The latter survey is conducted each summer aboard the *R/V Gloria Michelle* employing a stratified random sampling design and gear designed for Gulf of Maine conditions. The NSTC has placed primary dependence on the summer shrimp survey for fishery-independent data used in stock assessments, although the other survey data have also been valuable in assessing resource trends.

There has generally been good agreement between the NEFSC autumn survey index and fishery trends (Table 11, Fall kg/tow, and Figure 9). The index was close to all time highs at the beginning of the time series in the late 1960's and early 1970's when the Gulf of Maine Northern shrimp stock was at or near virgin levels. In the late 1970's the index declined precipitously as the fishery collapsed; this was followed by a substantial increase in the middle 1980's to early 1990's, with peaks in 1986, 1990 and 1994. This reflects recruitment and growth of the strong presumed 1982, 1987 and 1992 year classes and the above average 1993 year class. After declining to 0.90 kg/tow in 1996, the index rose sharply in 1999 to 2.32 kg per tow, well above the time series mean of 1.77 kg/tow. This is likely due to recruitment of the 1996 year class to the survey gear. Beginning in 2000, the fall survey index declined precipitously for two consecutive years reaching a low of 0.63 kg/tow in 2001, indicating very poor 1997 and 1998 year classes. From 2002 to 2006, the index generally increased, reaching unprecedented time series highs in 2006 and 2007 of 6.64 kg/tow and 4.13 kg/tow, respectively. From 2005 to 2008, the fall survey index was well above the time series mean of 1.77 kg/tow. From 2002 to 2011, landings generally rose each year as well, although some resource highs were not reflected in the fishery, likely due to poor market conditions for shrimp. Elevated fall survey indices observed since 2002 are indicative of robust assumed 2001 and 2004 year classes and moderate 2003, 2005, and 2007 year classes. Because the NEFSC fall survey changed vessels and survey protocols beginning in 2009, data collected for northern shrimp by the survey from 2009 on are not currently comparable to previous surveys and were not included in this assessment.

The Maine-New Hampshire inshore trawl survey takes place annually, during spring and fall, in five regions and three depth strata (1 = 5-20 fa, 2 = 21-35 fa, 3 = 36-55 fa). A deeper stratum (4 = > 55 fa) was added in 2003 (Figure 8a). The survey consistently catches shrimp in regions 1-4 (NH to Mt. Desert) and depths 3-4 (> 35 fa), and more are caught in the spring than the fall. The $\log_e$-transformed stratified mean weights per tow for *P. borealis* for the spring and fall surveys using regions 1-4 and depths 3-4 only are presented in Tables 8 and 11 and Figure 10. The Maine-New Hampshire index rose from 4.16 kg/tow during spring 2003 to 15.42 kg/tow during spring 2008. In 2009, the spring index dipped to 9.65 kg/tow. This was followed by an increase to 15.95 kg/tow in spring 2010 and to 17.05 kg/tow in spring 2011.

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the state-federal summer survey from 1984-2011 are given in Table 9 and Figures 8b and 11, and length-frequencies by year are provided in Figure 12. The $\log_e$ transformed mean weight per tow averaged 15.8 kg/tow from 1984 through 1990. Beginning in 1991, this index began to decline and averaged 10.2 kg/tow from 1991 through 1996. The survey mean weight per tow then declined further, averaging 6.5 kg/tow from 1997 through 2003, and reaching a time series low of 4.3 kg/tow in 2001. Between 2003 and 2006 the index increased markedly, reaching a new time series high in 2006 (66.0 kg/tow). Although 2006 was a high abundance year, as corroborated by the fall survey index, the 2006 summer survey index should be viewed with caution because it was based on only 29 survey tows compared with about 40 tows in most years (Table 9). The summer survey index was 16.8 kg/tow in 2008, and has dropped steadily since then, to 8.5 kg/tow in 2011, a value below the time series average of 13.7 kg/tow (Table 9). The total mean number of shrimp per tow demonstrated the same general trends over the time series (Table 9 and Figure 11).

The stratified mean catch per tow in numbers of 1.5-year old shrimp (Table 9, Figure 11, and graphically represented as the total number in the first (left-most) size modes in Figure 12) represents a recruitment index. Although these shrimp are not fully recruited to the survey gear, this index appears sufficient as a preliminary estimate of year class strength. This survey index indicated strong (more than 700 per tow) assumed 1987, 1992, 2001, and 2004 year classes. The assumed 1983, 2000, 2002, and 2006 age classes were weak (less than 100 per tow), well below the time series mean of 393 individuals per tow. From 2008 to 2010, the age 1.5 index varied around 500 individuals per tow (506, 554, and 475 individuals per tow, respectively), indicating moderate but above average assumed 2007, 2008, and 2009 year classes. The age 1.5 index dropped markedly to 41 individuals per tow in 2011, signifying a weak 2010 year class.

Individuals >22 mm will be fully recruited to the upcoming winter fishery (primarily age 3 and older) and thus survey catches of shrimp in this size category provide indices of harvestable numbers and biomass for the coming season (Table 9 and Figure 11). The harvestable biomass index exhibited large peaks in 1985 and 1990, reflecting the very strong assumed 1982 and 1987 year classes respectively. This index has varied from year to year but generally trended down until 2004. The 2001 index of 1.5 kg/tow represented a time series low, and is indicative of poor assumed 1997 and 1998 year classes. In 2002 the index increased slightly to 2.9 kg/tow, reflecting recruitment of the moderate 1999 year class to the index. The index subsequently dropped to the second lowest value in the time series (1.7 kg/tow) in 2003. From 2003 to 2006, the fully recruited index increased dramatically, reaching a time series high in 2006 (29.9 kg/tow). This increase may have been related to the continued dominance of the record 2001 year class, some of which may have survived into the summer of 2006, and to an unexplained increase in the number of female stage 1 shrimp (Figure 9), probably the 2003 year class. In

2007 the index declined to 4.1 kg/tow with the passing of the 2001 year class and the diminishing of the 2003 year class. The 2008 index increased to 10.8 kg/tow, reflecting the strong 2004 and moderate 2005 year classes. The >22 mm weight index declined slightly in 2009 to 8.5 kg/tow, still above the time series mean of 6.3 kg/tow. The moderate 2005 and 2007 year classes and perhaps a remnant of the strong 2004 year class contributed to the composition of the 2009 summer survey >22 mm index. In 2010, the >22 mm weight index dropped to 4.8 kg/tow due to the limited presence of the weak assumed 2006 year class and the passing of the 2005 year class. The index in 2010 was composed primarily of individuals from the moderate assumed 2007 and 2008 year classes, and possibly a remnant of the 2005 year class. In 2011, the >22 mm index declined further to 2.9 kg/tow due an apparent decline in the abundance of the 2007 year class, and to the overall small size (carapace length) of female shrimp from the moderate 2008 year class (Table 9 and Figure 12). Male shrimp from the assumed 2009 year class were also unusually small (Figure 12).

ENVIRONMENTAL CONDITIONS

Ocean temperature has an important influence on northern shrimp in the Gulf of Maine (Apollonio et al. 1986; Richards et al. 1996; Richards et al. in review). During the warm period of the 1950s, northern shrimp catches declined to zero despite continued fishing effort (Dow 1964). Spring ocean temperature has been linked to recruitment strength, with cooler temperatures creating better survival conditions for larvae. Spawner abundance also significantly influences recruitment strength. Timing of the larval hatch is influenced by temperature during late spring through early winter (Richards in review).

Ocean temperatures have been increasing since the mid-1900s (Figure 19A), and spring temperatures in GOM shrimp habitat areas were the highest on record during 2010 and 2011 (NEFSC trawl survey data, 1968-2011; Figures 19B and 19C). The start of the hatch period has become earlier as temperatures have increased (Figure 19D).

ANALYTICAL STOCK ASSESSMENT

Descriptive information for the Gulf of Maine shrimp fishery (total catch, port samples, trawl selectivity, survey catches, and life history studies) were modeled to estimate fishing mortality, stock abundance, and candidate target fishing levels. The analytical stock assessment comprises three fishery models. The Collie-Sissenwine Analysis, also called Catch-Survey Analysis (CSA) (Collie and Sissenwine 1983; Collie and Kruse 1998; Cadrin et al. 1999, Cadrin 2000) is a stage-based model that tracks abundance and mortality of recruits entering the fishery each year using total catches and summer survey indices. Surplus production analysis (Prager 1994, Prager et al. 1996) models the biomass dynamics of the stock with a longer time series of total landings and four survey indices of stock biomass. A yield-per-recruit and eggs-per-recruit model (Cadrin et al. 1999) simulates the life history of shrimp (including growth rates, transition rates, natural mortality, and fecundity) and fishing mortality on recruited shrimp using estimates of trawl selectivity to estimate yield and egg production at various levels of fishing mortality. The models provide guidance in determining the levels of fishing that are most productive and sustainable. See the Appendix for a discussion of natural mortality rates (M).

CSA results, assuming M=0.25, are summarized in Table 10 and Figures 13 and 14 – see the Appendix for results with M=0.40 and M=0.60. Abundance and catchability were relatively well estimated, and the model fit the data well. Estimates of new recruitment to the fishery averaged 0.6 billion individuals during 1985-1994, declined to an average of 0.5 billion during 1995 - 2004, and then rose again as the strong 2004 year class entered the fishery. New recruit abundance was 1.5 billion before the 2006 fishing season and 1.3 billion before the 2007 season, but declined to about 0.4 billion on average before the 2008-2011 fishing seasons. The estimate of abundance of new recruits to the 2012 fishery is 0.4 billion. Fully-recruited abundance averaged 0.7 billion individuals during 1985-1994, declined to 0.4 billion during 1995-2005 and peaked at 1.7 billion before the 2007 season. The 2008-2011 average of fully recruited shrimp remained high at 1.0 billion, but declined to 0.5 billion before the 2012 season. Total exploitable stock biomass estimates averaged about 10,700 mt during 1985-1994, declined to an average of 6,200 mt during 1995-2004 and reached a peak of 20,600 mt in 2006. Total exploitable stock biomass has declined steadily since then and was estimated as 6,500 mt before the 2012 fishing season. (Table 10, Figures 13, 14).

Annual estimates of fishing mortality (F) averaged 0.32 (24% exploitation) for the 1985 to 1994 fishing seasons (FMP target), peaked at 1.22 (64% exploitation) in the 1997 season then declined to lower levels (average F=0.23, 18% exploitation) during 2000-2009 (Table 10; Figures 13, 14). The highest F observed during 1985 to 1994, which is the FMP threshold F, was F_{1987}=0.41. The 2010 estimate of F rose to 0.45 (32% exploitation) and increased again to 0.68 (44% exploitation) in 2011. Recent patterns in F reflect the pattern in nominal fishing effort (Tables 4 and 10, Figures 6 and 13).

Precision of CSA estimates was assessed by bootstrap analysis, in which survey measurement errors were randomly re-sampled with replacement 1000 times to provide simulated replications of the model. Bootstrap results suggest that estimates of abundance, biomass and mortality were relatively precise (Figure 13). Retrospective analyses of the CSA model indicated relatively high stability in the estimates as additional years of data were added to the analysis (Figure 14b). Abundance estimates were more strongly affected by the exceptionally large 2006 suvey indices than were estimates of F. The retrospective analysis shows that terminal estimates from CSA have been somewhat optimistic (terminal year biomass biased high, F low).

Because of a lack of detailed information about discards, there were no analyses of discarding for this assessment.

An alternative method of estimating stock size and F was used to corroborate results from the CSA analysis. A surplus production model (ASPIC) was fit to seasonal catch and survey biomass indices from 1968 to 2011 (summarized in Table 11). Estimates of F and biomass from the surplus production model generally confirmed the pattern of estimates from the CSA model between 1985 and 2007 (Figures 15 and 16). However, some divergence in estimated biomass trends has occurred in recent years (2008-2012), where biomass from the surplus production model trends upward while biomass from the CSA trends downward. This difference is due in part to the three additional survey indices input to the surplus production model (Table 11). It is important to note that surplus production model-generated estimates of F and biomass trend similarly with those from CSA if only the summer survey index and commercial catch are included, as with the CSA (Figure 15, pink solid line with square symbols vs. red dashed line). Excluding additional indices was instructive in identifying reasons for the F and biomass divergence observed between models. Recent years' F and biomass estimates have been strongly influenced by the Maine-New Hampshire inshore spring survey index, available since 2003. This survey is weighted heavily in the model because of its relatively low inter-annual variability and when it is excluded, terminal years show a declining trend in biomass and a rise in F (Figure 15, yellow line with '-' symbols). Although the Maine-New Hampshire survey has indeed been shown to catch northern shrimp (Table 8, Figure 10), the segment of the population observed by this survey may vary from year to year as it is dependent on the timing of the spring offshore migration. Because this timing is not well documented and likely varies with the timing of egg-hatch and temperature or other environmental conditions, it is not clear whether the Maine-New Hampshire inshore spring survey adequately tracks the shrimp resource. Further agreement between the surplus production and CSA models is achieved by including only those surveys currently in operation (summer shrimp and ME-NH inshore spring) (Figure 15, green line with diamond symbols). These two surveys are weighted nearly equally and the model results reflect trends of the much longer summer shrimp index. The comparison of model runs informs us of the influence of historical data (such as the fall index) on recent F and biomass projections from the surplus production model. Although the fall trawl survey index has not been available since 2008, relatively high values in its terminal years still influence the current biomass estimate.

The surplus production analysis is useful for providing historical context of stock size and in illustrating F and biomass trends; however, it does not incorporate all available information (e.g. recruit trends); thus it is used as a sensitivity analysis. With both the CSA and surplus production models, terminal year values of fishing mortality and biomass are typically poorly estimated, possibly contributing to the divergence seen in recent years.

The precision of absolute F and biomass estimates from production models, such as ASPIC, is typically low because of insufficient information to estimate q (catchability) (Prager 1994). Because q may vary with population size (Sissenwine 1978), it is particularly difficult to estimate for northern shrimp, a stock where apparent year class strength varies markedly and stock size is driven by recruitment events unrelated to population size (NE SARC 2007). Alternatively, relative F (F/F_{MSY}) and relative biomass (B/B_{MSY}) are estimated more precisely and provide insight on stock dynamics (Table 11).

Yield per recruit and percent maximum spawning potential were estimated for the Gulf of Maine northern shrimp fishery (Table 12 and Figure 17, from Cadrin et al 1999). Yield per recruit was maximum at F=0.77 (F_{max}) (48% exploitation) assuming M=0.25. The increase in yield per unit F decreased to one tenth the initial increase at F=0.46 ($F_{0.1}$) (33% exploitation). Maximum spawning potential (i.e., with no F) was 2,395 eggs per recruit. Spawning potential was reduced by half at F=0.25 ($F_{50\%,}$ 20% exploitation).

As concluded by the Stock Assessment Review Committee (SARC) (NEFSC 1996), the stock was not replacing itself when spawning potential was reduced to less than 20% of maximum, and the stock collapsed when egg production was reduced further. Reproductive success for Gulf of Maine northern shrimp is related to population fecundity and spring ocean temperatures (Richards et al. 1996; see discussion under Environmental Conditions above). Therefore, $F_{20\%}$ may be an appropriate overfishing threshold, which would result in a target F well below 0.6. A sustainable target F may be the average F from 1985 through 1994, which was 0.32 (which allows ~40% of maximum egg production per recruit) (Table 12, Figure 17).

SUMMARY

Landings in the Gulf of Maine northern shrimp fishery declined after the mid 1990’s, from a high of 9,500 mt in 1996 to a low of 450 mt in 2002, the result of low abundances of shrimp and reductions in fishing effort. Since then, landings have increased to 5,000 mt in the 152-day 2008 season, and then declined to 2,500 mt in the 180-day 2009 season, well below the NSTC’s recommended cap of 5,100 mt, probably due to market limitations. Preliminary landings data from harvester reports for the 2010 season total 6,256 mt. The 2010 season was characterized by very high catch rates and improved market conditions. 2010 landings comprised mostly assumed 5-year-old female shrimp from the moderate 2005 year class, and the landings were above the

NSTC's recommended cap of 4,900 mt for shrimp of that size. Preliminary landings for 2011 are 5,944 mt, of mostly assumed 4-year-old shrimp from the above-average 2007 year class. 2011 landings were also above the NSTC's recommended cap of 4,000 mt, and may increase further as late reports come in. Late reporting (after September each year) has accounted for an average of about 10% of landings in recent years. The 2011 season was characterized by higher prices and high catch rates; catch rates in December were unusually high, on shrimp that seemed to have migrated inshore early.

The number of fishing vessels and trawl trips dropped from about 347 and 11,791 respectively in 1996 to 198 and 1,034 in 2002, and increased to 308 and 4,711 respectively in 2011 (preliminary). Of the 308 vessels that reported shrimp landings in 2011, 125 were trapping.

Trap catches accounted for about 12% of Maine's landings during 2001 to 2007, 18% during 2008 to 2010 (preliminary data), and 15% (preliminary data) during the truncated 2011 season.

Fishing mortality rates (F), as calculated by CSA, declined from 1.22 in 1997 to 0.12 in 2002, averaged 0.24 during 2003-2008, then rose to 0.45 in the 2010 and 0.68 in 2011. Terminal year estimates are the most poorly estimated however, and in recent years terminal F has been underestimated. The FMP target F was re-estimated in this assessment as $F_{1985\text{-}94}$=0.32, and the FMP threshold F_{1987}=0.41. The FMP target F was exceeded in every year during 1995-2000, and the FMP threshold F was exceeded in 1995-1999. Both the target F and the threshold F were exceeded in 2010 and 2011.

Total exploitable stock biomass as estimated from CSA averaged about 10,700 mt during 1985-1994, declined to less than 4,000 mt during 1999-2002, and climbed to a peak of 20,600 mt in 2006. Total exploitable stock biomass has declined steadily since then and is estimated as 6,500 mt before the 2012 fishing season, below the FMP biomass threshold of 9,000 mt, and near the FMP biomass limit of 6,000 mt. The NSTC notes that there is a high degree of uncertainty around terminal year biomass estimates, which have been over-estimated in recent years. Exceptionally high survey indices from the 2006 summer survey, which had fewer tows than usual, account for some of this uncertainty.

Size composition data from both the fishery and summer surveys indicate that good landings have followed the recruitment of strong (dominant) year classes. Poor landings from 1998 to 2004, as well as low biomass estimates, can be attributed in part to the below-average recruitment of the assumed 1995, 1997, 1998, 2000, and 2002 year classes. The strong 2001 and 2004 year classes have contributed to higher biomass estimates since then. In 2012, the female population will be comprised of the assumed 2007 and 2008 year classes (5-year-old and 4-year-old females respectively). Both of these year classes were of above average abundance when they first appeared in the 2008 and 2009 summer surveys. However, the 2007 year class was the primary component of the 2011 fishery, and the 2011 survey showed an apparent decline in its abundance relative to the 2008 year class, and an overall small size (carapace length) of the 2008 year class. Male shrimp from the assumed 2009 year class were also unusually small. The 2010 year class was very weak. The NSTC estimates that the shrimp in the 2012 fishery will be mostly 4-year-olds from the 2008 year class, and they are relatively small for their age.

The NSTC also notes that recent sea surface and bottom temperatures in the western Gulf of Maine have been unusually high, which may indicate an increasingly inhospitable environment for northern shrimp.

RECOMMENDATIONS

The NSTC bases its recommendations to the Section on its assessment of current stock status, the biology of the species, and the stated management goal of protecting and maintaining the stock at levels that will support a viable fishery on a sustainable resource (Amendment 2 to the FMP, ASMFC 2011).

The NSTC recommends that the Section continue its efforts to maintain fishing mortality at or below the FMP target value, currently estimated as $F_{1985\text{-}94}$=0.32. The NSTC also finds that recent GOM temperature data suggest the need to conserve spawners to compensate for what may be an increasingly unfavorable environment for northern shrimp.

Short-term commercial prospects for the 2012 fishing season are poor – the summer survey index of shrimp of carapace length greater than 22 mm (2.9 kg/tow) was lower than the 1984-2011 survey time series mean (6.3 kg/tow). Given the size composition of the 2011 survey catches, we expect catches in 2012 to be mostly composed of unusually small 4-year-old female shrimp. If the female shrimp fail to separate themselves from the smaller males, or if the fishery is conducted when and where the year classes are mixed, a "mixier" product may result, and an opportunity to conserve the moderate 2009 year class will be lost.

Catch in numbers (C) is a function of abundance (N) and exploitation rate (μ, which is a function of fishing mortality F and natural mortality M).

$$C = N\mu = NF\frac{1-e^{-(F+M)}}{F+M}$$

Using this relationship, it is possible to estimate projected landings (in numbers) in 2012 for various levels of F, from the CSA-estimated abundance of recruits and new recruits (Table 10) and assuming M= 0.25.

To convert landings in numbers to landings in weight, an assumption must be made about the mean weight of the shrimp caught in the upcoming fishery. The NSTC has investigated the relationship between the mean carapace length (mm) of female shrimp during the summer survey, and the mean weight (g) of an individual shrimp in the next fishing season, and found that the summer survey length can be used to predict the fishery mean weight (Figure 20a). Using this relationship, the mean weight of a shrimp in the 2012 fishery is predicted to be 9.81 g. Adjusting the summer survey female length index upward when there is a high proportion of female shrimp in the survey, and downward when there is a relatively large index for 2.5-age shrimp (the males), creates another relationship (Figure 20b). Using this relationship, the mean weight of a shrimp in 2012 would be about 9.99 g. There was a high proportion of female shrimp relative to males and juveniles in the 2011 survey due to the apparent weakness of the 2010 year class, but the 2010 year class would not be expected to be significantly exploited by the fishery; therefore the NSTC chose not to use the 9.99 g estimate. The NSTC also compared the shrimp size distribution from the 2011 summer survey with past surveys, and found that it was most similar to the distributions in the 2001 and 2007 surveys. Therefore the size distributions in the 2012 fishery may be similar to those of the 2002 and 2008 fisheries, in which the mean weight of a shrimp was 9.69 g and 10.11 g respectively. Using this range of weights to convert numbers of shrimp to landings in weight for varying F gives:

	Worst case scenario Like 2001 survey and 2002 fishery mean wt = 9.69g	**Most likely** Predicted from survey female size vs catch size the following season mean wt = 9.81g	**Best case scenario** Like 2007 survey and 2008 fishery mean wt = 10.11g
Fishing Mortality Rate for 2012	**Estimated Landings (mt)**	**Estimated Landings (mt)**	**Estimated Landings (mt)**
0.05	321	325	335
0.10	627	634	654
0.15	918	929	958
0.20	1,196	1,211	1,248
0.25	1,461	1,479	1,525
0.30	1,714	1,735	1,788
0.32	1,812	$\boxed{1{,}834}$	1,890
0.40	2,185	2,211	2,280
0.50	2,613	2,645	2,726
0.60	3,002	3,039	3,133
0.75	3,522	3,564	3,674
1.00	4,240	4,291	4,424
1.25	4,809	4,867	5,018

The three columns of estimated landings in the table above present a worst case (more small shrimp in the landings), average or most likely case (best fit to past data), and best case (fewer small shrimp in the landings) scenarios. The NSTC is basing their advice below on the most likely (middle) scenario.

If managers wish to achieve a fishing mortality rate of no more than F=0.32, the NSTC recommends a 2012 shrimp catch level at or below 1,834 mt.

If shrimp smaller than 9.81 g are caught in substantial numbers, the fishing mortality rate (F) will be higher for the same landed weight.

Yield-per-recruit and egg-per-recruit analyses (Table 12) show that shrimp reach both their potential maximum weight yield and maximum egg production at about ages 4-5. Therefore, protecting younger shrimp is recommended for both economical and biological reasons. Protecting egg-bearing females prior to egg hatch, which usually occurs during February and/or March, is also recommended. Shifting the focus of the fishery to second-year females (5-yr-old) would increase the spawning capacity of the population and help compensate for the expected negative effects of warming ocean temperatures.

The NSTC notes the uncertainty in the estimates of F and stock abundance associated with the terminal years of the CSA model, particularly when landings data are incomplete. There is also considerable uncertainty in projecting the exploitable biomass from the time of the summer survey to the fishing season, and in predicting the size composition of the catch in the upcoming season. The committee urges caution in selecting management options, since estimates of both F and stock abundance are subject to change in either direction, that is, these parameters may be over- or underestimated in any given year. Retrospective patterns in the CSA indicate that the terminal year estimates in recent years have been optimistic (over-estimating biomass and underestimating F).

The NSTC urges managers to continue to take whatever action is necessary to ensure timely reporting of landings. The committee also urges managers to ensure that the summer shrimp survey continues to be adequately funded and staffed.

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Table 1. U.S. Commercial landings (mt) of northern shrimp in the Gulf of Maine.

Year	Maine		Massachusetts		New Hampshire		Total		Price	Value
	Annual	Season	Annual	Season	Annual	Season	Annual	Season	$/Lb	$
1958	2.2		0.0		0.0		2.2		0.32	1,532
1959	5.5		2.3		0.0		7.8		0.29	5,002
1960	40.4		0.5		0.0		40.9		0.23	20,714
1961	30.5		0.3		0.0		30.8		0.20	13,754
1962	159.5		16.2		0.0		175.7		0.15	57,382
1963	244.3		10.4		0.0		254.7		0.12	66,840
1964	419.4		3.1		0.0		422.5		0.12	112,528
1965	941.3		8.0		0.0		949.3		0.12	245,469
1966	1,737.8		10.5		18.1		1,766.4		0.14	549,466
1967	3,141.2		10.0		20.0		3,171.2		0.12	871,924
1968	6,515.2		51.9		43.1		6,610.2		0.11	1,611,425
1969	10,993.1		1,773.1		58.1		12,824.3		0.12	3,478,911
1970	7,712.8		2,902.3		54.4		10,669.5		0.20	4,697,419
1971	8,354.8		2,724.0		50.8		11,129.6		0.19	4,653,203
1972	7,515.6		3,504.6		74.8		11,095.0		0.19	4,586,484
1973	5,476.6		3,868.2		59.9		9,404.7		0.27	5,657,348
1974	4,430.7		3,477.3		36.7		7,944.7		0.32	5,577,465
1975	3,177.2		2,080.0		29.4		5,286.6		0.26	3,062,721
1976	617.3		397.8		7.3		1,022.4		0.34	764,094
1977	142.1		236.9		2.2		381.2		0.55	458,198
1978	0.0		3.3		0.0		3.3		0.24	1,758
1979	32.8		405.9		0.0		438.7		0.33	320,361
1980	69.6		256.9		6.3		332.8		0.65	478,883
1981	530.0		539.4		4.5		1,073.9		0.64	1,516,521
1982	883.0		658.5		32.8		1,574.3		0.60	2,079,110
1983	1,029.2		508.2		36.5		1,573.9		0.67	2,312,073
1984	2,564.7		565.4		96.8		3,226.9		0.49	3,474,352
1985	2,957.0	2,946.4	1,030.5	968.0	207.4	216.5	4,194.9	4,130.9	0.44	3,983,599
1986	3,407.2	3,268.2	1,085.7	1,136.3	191.1	230.5	4,684.0	4,635.0	0.63	6,451,207
1987	3,534.2	3,680.2	1,338.7	1,427.9	152.5	157.9	5,025.4	5,266.0	1.10	12,740,583
1988	2,272.5	2,258.4	632.7	619.6	173.1	157.6	3,078.3	3,035.6	1.10	7,391,778
1989	2,544.8	2,384.0	751.6	699.9	314.3	231.5	3,610.7	3,315.4	0.98	7,177,660
1990	2,962.1	3,236.3	993.4	974.9	447.3	451.3	4,402.8	4,662.5	0.72	7,351,421
1991	2,431.5	2,488.6	737.7	814.6	208.3	282.1	3,377.5	3,585.3	0.91	7,208,839
1992	2,990.4	3,070.6	291.7	289.3	100.1	100.1	3,382.2	3,460.0	0.99	7,547,942
1993	1,563.1	1,492.5	300.3	292.8	441.2	357.6	2,304.6	2,142.9	1.07	5,038,053
1994	2,815.4	2,239.7	381.9	247.5	521.0	428.0	3,718.3	2,915.2	0.75	4,829,107
1995		5,013.7		670.1		772.8		6,456.6	0.90	12,828,031
1996		8,107.1		660.6		771.7		9,539.4	0.73	15,341,506
1997		6,086.9		366.4		666.2		7,119.5	0.79	12,355,873
1998		3,481.3		240.3		445.2		4,166.8	0.96	8,811,939
1999		1,573.2		75.7		217.0		1,865.9	0.91	3,762,044
2000		2,085.3		110.3		212.3		2,407.9	0.79	4,190,546
2001		1,075.2		49.4		206.4		1,331.0	0.86	2,534,095
2002		391.6		8.1		53.0		452.7	1.08	1,077,534
2003		1,203.7		27.7		113.0		1,344.4	0.87	2,590,917
2004		1,926.9		21.3		183.2		2,131.4	0.44	2,089,636
2005		2,270.2		49.6		290.3		2,610.1	0.57	3,261,648
2006		2,201.6		30.0		91.1		2,322.7	0.37	1,885,978
2007		4,469.3		27.5		382.9		4,879.7	0.38	4,087,121
2008		4,515.8		29.9		416.8		4,962.4	0.49	5,407,374
2009		2,315.7		MA & NH combined		185.6		2,501.2	0.40	2,216,411
2010		5,714.3		34.9		506.8		6,256.1	0.55	7,528,670
2011		5,117.6		195.1		631.2		5,943.9	0.75	9,828,043

2010 and 2011 are preliminary.

Table 2. Distribution of landings (metric tons) in the Gulf of Maine northern shrimp fishery by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1987 Season, 182 days, Dec 1 - May 31								
Maine	485.9	906.2	1,192.7	672.9	287.6	127.9	7.0	3,680.2
Mass.	103.5	260.0	384.9	310.2	180.8	182.8	5.7	1,427.9
N.H.	18.4	53.6	62.8	15.7	7.3	0.0	0.1	157.9
Total	607.8	1,219.8	1,640.4	998.8	475.7	310.7	12.8	5,266.0
1988 Season, 183 days, Dec 1 - May 31								
Maine	339.7	793.9	788.1	243.6	24.6	67.3	1.2	2,258.4
Mass.	14.4	225.8	255.0	104.9	8.6	10.9	0.0	619.6
N.H.	13.0	72.6	53.7	14.9	0.3	0.0	3.1	157.6
Total	367.1	1,092.3	1,096.8	363.4	33.5	78.2	4.3	3,035.6
1989 Season, 182 days, Dec 1 - May 31								
Maine	353.6	770.5	700.6	246.4	218.7	94.2		2,384.0
Mass.	26.2	197.5	154.9	104.8	160.9	55.6		699.9
N.H.	28.5	106.9	77.0	15.4	3.7	0.0		231.5
Total	408.3	1,074.9	932.5	366.6	383.3	149.8	0.0	3,315.4
1990 Season, 182 days, Dec 1 - May 31								
Maine	512.4	778.4	509.8	638.7	514.1	282.8	0.1	3,236.3
Mass.	75.6	344.5	184.8	100.2	159.0	110.0	0.8	974.9
N.H.	111.3	191.7	116.2	30.7	1.4			451.3
Total	699.3	1,314.6	810.8	769.6	674.5	392.8	0.9	4,662.5
1991 Season, 182 days, Dec 1 - May 31								
Maine	238.3	509.2	884.1	455.0	251.8	148.2	2.0	2,488.6
Mass.	90.6	174.7	176.0	131.2	93.3	133.8	15.0	814.6
N.H.	107.3	104.4	33.8	27.8	7.8	1.0		282.1
Total	436.2	788.3	1,093.9	614.0	352.9	283.0	17.0	3,585.3
1992 Season, 153 days, Dec 15 - May 15								
Maine	181.2	881.0	1,295.0	462.6	163.6	87.2		3,070.6
Mass.	17.1	148.3	73.3	47.6	2.9		0.1	289.3
N.H.	33.4	47.0	11.9	6.8	1.0			100.1
Total	231.7	1,076.3	1,380.2	517.0	167.5	87.2	0.1	3,460.0
1993 Season, 138 days, Dec 14 - April 30								
Maine	101.0	369.1	597.1	297.5	127.8			1,492.5
Mass.	19.6	82.0	81.9	62.3	42.0	5.0		292.8
N.H.	33.5	85.4	101.8	77.0	59.9			357.6
Total	154.1	536.5	780.8	436.8	229.7	5.0	0.0	2,142.9
1994 Season, 122 days, Dec 15 - Apr 15								
Maine	171.5	647.8	972.1	399.6	48.7			2,239.7
Mass.	27.1	68.0	100.8	38.8	12.8			247.5
N.H.	117.2	124.3	128.7	49.6	8.2			428.0
Total	315.8	840.1	1,201.6	488.0	69.7	0.0	0.0	2,915.2

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	747.3	1,392.9	1,336.0	912.1	625.4			5,013.7
Mass.	160.6	154.0	104.1	111.0	139.5		0.9	670.1
N.H.	210.2	186.8	118.3	158.5	99.0			772.8
Total	1,118.1	1,733.7	1,558.4	1,181.6	863.9	0.0	0.9	6,456.6
1996 Season, 152 days, Dec 1 - May 31, 1 day per week off								
Maine	1,122.0	1,693.1	3,236.9	795.6	361.5	897.6	0.4	8,107.1
Mass.	167.9	106.7	190.7	67.2	66.5	60.3	1.3	660.6
N.H.	189.8	169.5	234.0	81.9	78.8	17.1	0.6	771.7
Total	1,479.7	1,969.3	3,661.6	944.7	506.8	975.0	2.3	9,539.4
1997 Season, 156 days, Dec 1 - May 27, two 5-day and four 4-day blocks off								
Maine	1,178.0	1,095.8	1,749.3	758.4	766.8	538.2	0.4	6,086.9
Mass.	90.2	110.4	111.4	49.0	1.2	0.5	3.7	366.4
N.H.	185.6	104.1	140.1	108.4	85.8	42.2	0.0	666.2
Total	1,453.8	1,310.3	2,000.8	915.8	853.8	580.9	4.1	7,119.5
1998 Season, 105 days, Dec 8 - May 22, weekends off except Mar 14-15, Dec 25-31 and Mar 16-31 off.								
Maine	511.1	926.8	1,211.1	401.0	228.7	202.6		3,481.3
Mass.	49.1	73.3	88.6	14.0	15.3			240.3
N.H.	89.4	106.9	143.5	54.3	49.0	2.1		445.2
Total	649.6	1,107.0	1,443.2	469.3	293.0	204.7	0.0	4,166.8
1999 Season, 90 days, Dec 15 - May 25, weekends, Dec 24 - Jan 3, Jan 27-31, Feb 24-28, Mar 16-31, and Apr 29 - May 2 off.								
Maine	79.9	192.7	599.3	247.9	205.3	248.1		1,573.2
Mass.	25.0	23.8	16.0	2.5	8.4			75.7
N.H.	46.5	63.2	52.2	10.0	36.5	8.6		217.0
Total	151.4	279.7	667.5	260.4	250.2	256.7	0.0	1,865.9
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		609.6	1,287.2	188.5				2,085.3
Mass.		17.9	78.7	13.7				110.3
N.H.		39.6	131.1	41.6				212.3
Total	0.0	667.1	1,497.0	243.8	0.0	0.0	0.0	2,407.9
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May								
Maine		575.8	432.8	36.6	29.8	0.3		1,075.2
Mass.		38.5	9.0	1.9		0.0		49.4
N.H.		127.9	37.4	12.1	29.0			206.4
Total	0.0	742.2	479.2	50.5	58.8	0.3	0.0	1,331.0
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			306.8	84.8				391.6
Mass.			5.7	2.3				8.1
N.H.			38.6	14.4				53.0
Total	0.0	0.0	351.2	101.5	0.0	0.0	0.0	452.7

Table 2 continued – Landings by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		534.7	668.0	0.4			0.6	1,203.7
Mass.		12.0	15.7					27.7
N.H.		30.9	82.1					113.0
Total	0.0	577.6	765.8	0.4	0.0	0.0	0.6	1,344.4
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	1.8	526.2	945.1	446.4	4.7	2.7	0.04	1,926.9
Mass.		5.2	12.7	3.3				21.3
N.H.		27.3	94.8	61.1				183.2
Total	1.8	558.7	1,052.6	510.9	4.7	2.7	0.04	2,131.4
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	75.0	377.9	894.7	922.6			0.01	2,270.2
Mass.	7.2	8.1	24.9	9.4				49.6
N.H.	17.3	53.5	175.4	44.1				290.3
Total	99.5	439.5	1,095.0	976.0	0.0	0.0	0.01	2,610.1
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	144.2	691.6	896.9	350.8	118.0			2,201.6
Mass.	5.3	9.2	7.4	7.6	0.4			30.0
N.H.	3.4	27.9	9.6	43.8	6.5			91.1
Total	152.9	728.7	914.0	402.2	124.9	0.0	0.0	2,322.7
2007 Season, 151 days, Dec 1 - Apr 30								
Maine	761.9	1,480.5	1,590.4	481.9	154.2	0.4	0.03	4,469.3
Mass.	6.6	12.6	4.8	3.5				27.5
N.H.	52.5	222.6	81.6	14.0	12.1			382.9
Total	821.0	1,715.7	1,676.8	499.4	166.3	0.4	0.03	4,879.7
2008 Season, 152 days, Dec 1 - Apr 30								
Maine	408.6	1,053.6	2,020.4	983.8	49.3		0.1	4,515.8
Mass.	4.3	3.2	7.9	14.5				29.9
N.H.	94.2	123.7	161.6	35.7	1.7			416.8
Total	507.0	1,180.5	2,189.9	1,034.0	51.0	0.0	0.1	4,962.4
2009 Season, 180 days, Dec 1 - May 29								
Maine	134.6	595.9	988.2	560.1	34.9	1.8	0.2	2,315.7
Mass.& NH	20.2	92.7	68.8	1.2	2.6			185.6
Total	154.8	688.6	1,057.0	561.3	37.5	1.8	0.2	2,501.2
***2010** Season, 156 days, Dec 1 - May 5								
Maine	264.1	1,689.2	2,948.8	524.5	241.7	45.7	0.4	5,714.3
Mass.	0.4	16.5	17.7	0.3				34.9
N.H.	112.8	152.4	200.0	14.2	25.2	2.2		506.8
Total	377.3	1,858.2	3,166.5	539.0	266.9	47.9	0.4	6,256.1

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
***2011** Season, 90 days, Dec 1 - Feb 28								
Maine	690.1	2,385.6	2,041.4	0.5				5,117.6
Mass.	20.8	99.6	74.7					195.1
N.H.	93.1	303.7	234.4					631.2
Total	803.9	2,788.9	2,350.6	0.5	0.0	0.0	0.0	5,943.9

* Preliminary data

Table 3. Distribution of landings (metric tons) in the Maine northern shrimp fishery by season, gear type, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	% of total
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May									
Trawl		533.0	360.1	30.9	29.8	0.3		954.0	89%
Trap		42.9	72.6	5.7				121.2	11%
Total	0.0	575.8	432.8	36.6	29.8	0.3	0.0	1,075.2	
2002 Season, 25 days, Feb 15 - Mar 11									
Trawl			263.6	77.2				340.8	87%
Trap			43.2	7.6				50.8	13%
Total	0.0	0.0	306.8	84.8	0.0	0.0	0.0	391.6	
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off									
Trawl		467.2	518.8	0.4			0.6	987.0	82%
Trap		67.5	149.2					216.7	18%
Total	0.0	534.7	668.0	0.4	0.0	0.0	0.6	1,203.7	
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off									
Trawl	1.8	514.0	905.5	430.0	4.7	2.7	0.04	1858.7	96%
Trap		12.2	39.5	16.5				68.1	4%
Total	1.8	526.2	945.1	446.4	4.7	2.7	0.04	1926.9	
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off									
Trawl	75.0	369.4	770.6	663.6			0.01	1878.5	83%
Trap		8.6	124.0	259.0				391.6	17%
Total	75.0	377.9	894.7	922.6	0.0	0.0	0.01	2270.2	
2006 Season, 140 days, Dec 12 - Apr 30									
Trawl	144.1	675.0	733.8	256.9	117.1			1927.0	88%
Trap	0.1	16.6	163.1	93.9	0.9			274.6	12%
Total	144.2	691.6	896.9	350.8	118.0	0.0	0.0	2201.6	
2007 Season, 151 days, Dec 1 - Apr 30									
Trawl	758.2	1,443.3	1,275.6	362.1	143.6	0.4	0.0	3,983.2	89%
Trap	3.7	37.2	314.7	119.8	10.6			486.1	11%
Total	761.9	1,480.5	1,590.4	481.9	154.2	0.4	0.0	4,469.3	
2008 Season, 152 days, Dec 1 - Apr 30									
Trawl	408.5	989.6	1,680.8	603.4	42.6		0.1	3,724.9	82%
Trap	0.1	64.0	339.6	380.4	6.7			790.8	18%
Total	408.6	1,053.6	2,020.4	983.8	49.3	0.0	0.1	4,515.8	
2009 Season, 180 days, Dec 1 - May 29									
Trawl	134.3	579.7	780.9	405.4	33.6	1.8	0.2	1,935.9	84%
Trap	0.4	16.2	207.3	154.7	1.3			379.8	16%
Total	134.6	595.9	988.2	560.1	34.9	1.8	0.2	2,315.7	
***2010** Season, 156 days, Dec 1 - May 5									
Trawl	263.4	1,494.9	2,125.0	338.3	238.4	45.7	0.4	4,506.0	79%
Trap	0.7	194.3	823.8	186.2	3.3			1,208.3	21%
Total	264.1	1,689.2	2,948.8	524.5	241.7	45.7	0.4	5,714.3	
***2011** Season, 90 days, Dec 1 - Feb 28									
Trawl	688.5	2,069.6	1,589.0	0.5				4,347.6	85%
Trap	1.5	314.7	452.5					768.7	15%
Total	690.1	2,384.3	2,041.4	0.5	0.0	0.0	0.0	5,116.3	

* Preliminary data

Table 4. Distribution of fishing effort (number of trawl trips) in the Gulf of Maine northern shrimp fishery by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1987 Season, 182 days, Dec 1 - May 31								
Maine	993	2,373	3,073	2,241	617	340	16	9,653
Mass.	325	354	414	426	283	317	164	2,283
N.H.	67	164	175	95	28		32	561
Total	1,385	2,891	3,662	2,762	928	657		12,285
1988 Season, 183 days, Dec 1 - May 31								
Maine	972	2,183	2,720	1,231	193	122		7,421
Mass.	28	326	426	315	26	57		1,178
N.H.	72	231	236	99	3			641
Total	1,072	2,740	3,382	1,645	222	179		9,240
1989 Season, 182 days, Dec 1 - May 31								
Maine	958	2,479	2,332	936	249	84		7,038
Mass.	103	479	402	254	297	102		1,637
N.H.	120	369	312	69	16			886
Total	1,181	3,327	3,046	1,259	562	186		9,561
1990 Season, 182 days, Dec 1 - May 31								
Maine	1,036	1,710	1,529	1,986	897	238		7,396
Mass.	147	459	273	202	175	118		1,374
N.H.	178	363	284	157	6			988
Total	1,361	2,532	2,086	2,345	1,078	356		9,758
1991 Season, 182 days, Dec 1 - May 31								
Maine	568	1,286	2,070	1,050	438	139		5,551
Mass.	264	416	401	231	154	147		1,613
N.H.	279	285	135	82	22	1		804
Total	1,111	1,987	2,606	1,363	614	287		7,968
1992 Season, 153 days, Dec 15 - May 15								
Maine	411	1,966	2,700	1,222	318	141		6,758
Mass.	59	337	145	101	41			683
N.H.	96	153	76	29	3			357
Total	566	2,456	2,921	1,352	362	141		7,798
1993 Season, 138 days, Dec 14 - April 30								
Maine	249	1,102	1,777	1,032	227			4,387
Mass.	60	200	250	185	72			767
N.H.	76	246	275	256	151			1,004
Total	385	1,548	2,302	1,473	450			6,158
1994 Season, 122 days, Dec 15 - Apr 15								
Maine	265	1,340	1,889	1,065	122			4,681
Mass.	58	152	147	83	15			455
N.H.	169	228	266	173	18			854
Total	492	1,720	2,302	1,321	155			5,990

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	879	2,341	2,641	1,337	694			7,892
Mass.	145	385	275	157	109			1,071
N.H.	189	331	279	359	344			1,502
Total	1,213	3,057	3,195	1,853	1,147			10,465
1996 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	1,341	2,030	3,190	1,461	444	457		8,923
Mass.	299	248	325	269	106	126		1,373
N.H.	331	311	389	248	155	61		1,495
Total	1,971	2,589	3,904	1,978	705	644		11,791
1997 Season, 156 days, Dec 1- May 31, two 5-day and four 4-day blocks off								
Maine	1,674	1,753	2,737	1,178	793	530		8,665
Mass.	184	226	245	114	7	1		777
N.H.	277	245	301	218	189	62		1,292
Total	2,135	2,224	3,283	1,510	989	593		10,734
1998 Season, 105 days, Dec 8-May 22, weekends off except Mar 14-15, Dec 25-31 and Mar 16-31 off.								
Maine	852	1,548	1,653	725	346	189		5,313
Mass.	94	200	148	70	3	1		515
N.H.	141	216	182	134	83	22		778
Total	1,086	1,964	1,983	929	432	212		6,606
1999 Season, 90 days, Dec 15 - May 25, weekends, Dec 24 - Jan 3, Jan 27-31, Feb 24-28, Mar 16-31, and Apr 29 - May 2 off.								
Maine	190	556	1,125	553	324	172		2,920
Mass.	39	57	71	9	40			216
N.H.	82	192	213	44	123	21		675
Total	311	805	1,409	606	487	193		3,811
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		653	1,838	401				2,892
Mass.		23	100	27				150
N.H.		36	179	78				293
Total		712	2,117	506				3,335
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 15 off, experimental offshore fishery in May								
Maine		1,500	1,214	112	43	6		2,875
Mass.		111	48	10		1		170
N.H.		303	143	27	30			503
Total	0	1,914	1,405	149	73	7	0	3,548
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			595	236				831
Mass.			19	9				28
N.H.			119	56				175
Total	0	0	733	301	0	0	0	1,034

Table 4 continued – Trawl trips by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		850	1,081	1				1,932
Mass.		41	50					91
N.H.		81	151					232
Total	0	972	1,282	1	0	0	0	2,255
2004 Season, 40days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	7	566	965	382	13	14	6	1,953
Mass.		9	36	11				56
N.H.		46	147	66				259
Total	7	621	1,148	459	13	14	6	2,268
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	140	647	953	778			1	2,519
Mass.	15	18	49	23				105
N.H.	24	76	216	77				393
Total	179	741	1,218	878	0	0	1	3,017
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	145	490	563	273	88			1,559
Mass.	10	16	16	15	1			58
N.H.	5	23	19	52	10			109
Total	160	529	598	340	99	0	0	1,726
2007 Season, 151 days, Dec 1 - Apr 30								
Maine	425	977	921	349	119	1	3	2,795
Mass.	10	18	9	8				45
N.H.	26	115	71	17	27			256
Total	461	1,110	1,001	374	146	1	3	3,096
2008 Season, 152 days, Dec 1 - Apr 30								
Maine	414	1,062	1,393	661	51	0	9	3,590
Mass.	8	9	8	13				38
N.H.	63	141	125	33	5			367
Total	485	1,212	1,526	707	56	0	9	3,995
2009 Season, 180 days, Dec 1 - May 29								
Maine	130	705	673	381	32	5	1	1,927
Mass.& NH	12	95	59	2	1			169
Total	142	800	732	383	33	5	1	2,096
***2010** Season, 156 days, Dec 1 - May 5								
Maine	238	1,229	1,512	449	162	33	1	3,624
Mass.	4	22	21	1				48
N.H.	55	126	151	21	52	4		409
Total	297	1,377	1,684	471	214	37	1	4,081

* Preliminary data

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
***2011** Season, 90 days, Dec 1 - Feb 28								
Maine	560	1,897	1,514	1				3,972
Mass.	28	92	73					193
N.H.	108	240	198					546
Total	696	2,229	1,785	1	0	0	0	4,711

Table 5. Distribution of fishing trips in the Maine northern shrimp fishery by season, gear type, and month. – Table 5 data are not available for 2011.

Table 6. Estimated numbers of vessels in the Gulf of Maine northern shrimp fishery by fishing season and state.

Season	Maine			Massachusetts	New Hampshire	Total
	Trawl	Trap	Total			
1980			15-20	15-20		30-40
1981			~75	~20-25		~100
1982			>75	~20-25		>100
1983			~164	~25	~5-8	~197
1984			239	43	6	288
1985			~231	~40	~17	~300
1986						~300
1987			289	39	17	345
1988			~290	~70	~30	~390
1989			~230	~50	~30	~310
1990			~220			~250
1991			~200	~30	~20	~250
1992			~259	~50	16	~325
1993			192	52	29	273
1994			178	40	29	247
1995						
1996			275	43	29	347
1997			238	32	41	311
1998			195	33	32	260
1999			181	27	30	238
2000			249	15	23	287
2001	174	60	234	19	27	275
2002	117	52	168	7	23	198
2003	142	49	191	12	22	222
2004	114	56	170	7	15	192
2005	102	64	166	9	22	197
2006	68	62	129	4	11	144
2007	97	84	179	3	15	196
2008	121	94	215	4	15	234
2009	80	78	158	12 (MA and NH combined)		170
*2010	123	112	234	5	15	254
*2011	156	125	276	12	20	308

note that some boats reported both trapping and trawling

* preliminary

Table 7. Gulf of Maine northern shrimp trawl catch rates by season. Mean CPUE in lbs/hour towed is from Maine port sampling. Mean catch in lbs/trip is from NMFS weighout and logbook data for trawl catches for all states.

Season	Maine pounds per hour towing			Pounds/trip
	Inshore (<55F)	Offshore (>55F)	Combined	
1991	94	152	140	988
1992	132	93	117	974
1993	82	129	92	767
1994	139	149	141	1,073
1995	172	205	193	1,362
1996	340	203	251	1,714
1997	206	192	194	1,454
1998	158	151	154	1,317
1999	148	147	147	1,067
2000	279	224	272	1,444
2001	100	135	109	752
2002	223	91	194	857
2003	174	215	182	1,102
2004	361	310	351	2,006
2005	235	212	228	1,621
2006	572	345	499	2,616
2007	531	477	507	3,129
2008	350	327	343	2,302
2009	400	315	370	2,231
*2010	424	354	401	2,727
*2011	334	435	347	2,422

* Pounds/trip are preliminary

Table 8. Stratified retransformed mean weights (kg) per tow of northern shrimp collected during the Maine - New Hampshire inshore trawl surveys by year, regions 1-4 (NH to Mt. Desert) and depths 3-4 (> 35 fa.) only, with number of tows (n) and 80% confidence intervals.

	Spring				Fall			
	kg/tow	n	80% CI		kg/tow	n	80% CI	
2003	**4.16**	40	3.40	5.05	**1.91**	33	1.35	2.60
2004	**3.87**	42	3.31	4.51	**1.53**	38	1.04	2.14
2005	**7.81**	40	6.60	9.21	**3.59**	25	2.46	5.10
2006	**10.99**	46	8.50	14.13	**2.06**	38	1.43	2.84
2007	**10.70**	43	7.93	14.33	**4.04**	45	3.15	5.13
2008	**15.42**	45	12.72	18.64	**3.59**	37	2.32	5.36
2009	**9.65**	45	7.67	12.09	**2.73**	41	2.27	3.27
2010	**15.95**	48	12.60	20.12	**2.11**	36	1.67	2.61
***2011**	**17.05**	51	14.13	20.53				

*2011 data are preliminary.

Table 9. Stratified* retransformed mean numbers and weights per tow of northern shrimp collected during *R/V Gloria Michelle* state/federal summer surveys.

		Log$_e$ retransformed				
	N	Age-1.5	>22 mm**	>22 mm	Total	Total
Year	Tows	Number	Number	Weight (kg)	Number	Weight (kg)
1984		18	316	3.4	1,152	10.5
1985	44	332	1,169	11.5	1,825	17.7
1986	40	358	860	10.0	1,695	19.6
1987	41	342	854	9.5	1,533	15.4
1988	41	828	298	3.4	1,269	12.8
1989	43	276	564	6.1	1,884	17.0
1990	43	142	1,127	12.0	1,623	18.1
1991	43	482	657	8.0	1,256	11.7
1992	45	282	397	4.8	955	9.4
1993	46	757	250	2.8	1,157	9.1
1994	43	368	243	2.7	984	8.7
1995	35	292	628	7.0	1,449	13.3
1996	32	232	358	4.0	776	8.8
1997	40	374	245	2.8	762	7.7
1998	35	134	170	1.9	583	6.3
1999	42	114	174	1.9	398	5.8
2000	35	450	283	3.2	808	6.4
2001	36	18	146	1.5	451	4.3
2002	38	1,164	261	2.9	1,445	9.2
2003	37	11	173	1.7	564	5.5
2004	35	286	519	5.3	887	10.3
2005	46	1,752	871	10.3	3,661	23.4
2006	29	374	2,773	29.9	9,998	66.0
2007	43	28	412	4.1	887	11.5
2008	38	506	995	10.8	1,737	16.8
2009	49	555	702	8.5	1,627	15.4
2010	49	475	413	4.8	1,373	13.9
2011	47	41	290	2.9	765	8.5
Mean	41	393	577	6.3	1,554	13.7
Median	41	337	405	4.5	1,206	11.0

*Based on strata 1, 3, 5, 6, 7 and 8.
**Will be fully recruited to the winter fishery.

Table 10. Summary of results from CSA analysis, Gulf of Maine northern shrimp.

Fishing Season	New Recruits (millions)	Fully-Recruited (millions)	F (NR+FR)	Biomass (1000 mt)	Exploitation Rate
1985	716	663	0.34	10.00	25%
1986	750	766	0.31	12.82	24%
1987	574	863	0.41	13.01	29%
1988	437	746	0.24	10.81	19%
1989	693	721	0.26	9.57	20%
1990	738	850	0.38	12.13	28%
1991	477	850	0.32	12.52	24%
1992	348	753	0.31	10.58	24%
1993	310	628	0.27	8.48	20%
1994	493	560	0.34	6.92	26%
1995	910	582	0.61	10.12	41%
1996	916	631	0.85	12.20	52%
1997	598	514	1.22	8.98	63%
1998	461	256	0.86	4.88	52%
1999	328	235	0.56	3.98	38%
2000	246	251	0.63	3.96	42%
2001	288	205	0.38	3.48	28%
2002	219	263	0.12	3.65	9%
2003	465	335	0.20	4.60	15%
2004	349	512	0.33	6.20	25%
2005	697	481	0.26	9.41	20%
2006	1,535	708	0.11	14.32	8%
2007	1,257	1,569	0.24	20.65	19%
2008	341	1,726	0.31	17.49	24%
2009	485	1,181	0.15	15.25	12%
2010	490	1,115	0.45	14.79	32%
2011	468	797	0.68	10.05	44%
2012	371	498		6.48	
Overall mean	570	688	0.41	9.90	28%
.985-94 mean	553	740	0.32	10.68	24%

Table 11a. Input values and summary of results from surplus production analysis (ASPIC), Gulf of Maine northern shrimp, Run 1, using all survey indices.

	Input					Results			
Survey Year	Fall (kg/tow)	Maine (kg/tow)	Summer (kg/tow)	Spring ME/NH (kg/tow)	Catch (mt)*	Biomass (1000 mt)	F	B/Bmsy	F/Fmsy
1968	3.20	45.80			6,610	38.68	0.17	0.95	1.01
1969	2.70	31.20			12,824	38.93	0.36	0.95	2.13
1970	3.70	40.80			10,670	32.86	0.35	0.81	2.07
1971	3.00	9.40			11,130	28.63	0.43	0.70	2.55
1972	3.30	7.00			11,095	23.45	0.55	0.57	3.25
1973	1.90	7.80			9,405	17.48	0.64	0.43	3.82
1974	0.80	4.90			7,945	12.10	0.86	0.30	5.10
1975	0.90	6.70			5,287	6.91	1.11	0.17	6.59
1976	0.60	4.80			1,022	3.13	0.33	0.08	1.94
1977	0.20	1.60			381	3.12	0.11	0.08	0.65
1978	0.40	3.20			3	3.86	0.00	0.09	0.00
1979	0.50	4.40			439	5.30	0.07	0.13	0.44
1980	0.50	2.70			333	6.73	0.04	0.16	0.26
1981	1.50	3.00			1,074	8.74	0.11	0.21	0.66
1982	0.30	2.00			1,574	10.52	0.14	0.26	0.82
1983	1.00	4.20			1,574	12.24	0.12	0.30	0.70
1984	1.90		10.47		3,227	14.42	0.22	0.35	1.29
1985	1.60		17.69		4,131	15.28	0.27	0.37	1.60
1986	2.50		19.61		4,635	15.34	0.31	0.38	1.82
1987	1.70		15.40		5,266	14.85	0.37	0.36	2.20
1988	1.20		12.76		3,036	13.53	0.22	0.33	1.29
1989	1.81		16.95		3,315	14.40	0.22	0.35	1.33
1990	2.04		18.12		4,663	15.16	0.31	0.37	1.86
1991	0.44		11.68		3,585	14.59	0.24	0.36	1.43
1992	0.41		9.43		3,460	15.10	0.22	0.37	1.33
1993	1.85		9.14		2,143	15.87	0.13	0.39	0.75
1994	2.24		8.69		2,915	18.26	0.15	0.45	0.90
1995	1.22		13.29		6,457	20.31	0.33	0.50	1.96
1996	0.90		8.77		9,539	18.86	0.59	0.46	3.52
1997	1.12		7.73		7,120	13.67	0.61	0.34	3.62
1998	1.99		6.33		4,167	9.92	0.45	0.24	2.69
1999	2.32		5.78		1,866	8.50	0.21	0.21	1.25
2000	1.28		6.39		2,408	9.30	0.25	0.23	1.50
2001	0.63		4.33		1,331	9.72	0.13	0.24	0.75
2002	1.70		9.16		453	11.49	0.04	0.28	0.21
2003	1.08		5.45	4.16	1,344	14.73	0.08	0.36	0.49
2004	1.58		10.27	3.87	2,131	17.76	0.11	0.44	0.66
2005	2.77		23.38	7.81	2,610	20.57	0.12	0.50	0.71
2006	6.64		65.99	10.99	2,323	23.36	0.09	0.57	0.55
2007	4.13		11.51	10.70	4,880	26.89	0.18	0.66	1.05
2008	3.05		16.77	15.42	4,962	28.16	0.17	0.69	1.02
2009	n/a		15.44	9.65	2,501	29.48	0.08	0.72	0.47
2010	n/a		13.94	15.95	6,256	33.49	0.19	0.82	1.10
2011			8.47	17.05	5,944	33.90	0.17	0.83	1.03
2012						34.65		0.85	
Average	**1.77**		**13.68**	**10.62**	**4,273**	**17.43**	**0.27**		
					1971-74 average:	20.42	0.62		
					1985-94 average:	15.70	0.25		
					2009-11 (3-yr) average:	32.29	0.15		

* preliminary data

Table 11b. Results of surplus production analysis (ASPIC) sensitivity runs.

See Table 11a for details from Run 1 (using all survey indices).
The second run omits the ME/NH spring survey index.
The third run omits all indices except the summer survey.
The fourth run includes only the summer survey and MH/NH spring survey indices.
The fifth run includes all survey indices except the fall.
The sixth run includes all survey indices except the old Maine survey.

	Fishing Mortality (F)						Starting Biomass (thousand mt)					
YEAR	ALL INDICES (Run 1)	WITHOUT Spring ME-NH Index	ONLY Summer Shrimp Index	CURRENTLY-RUNNING INDICES (Summer Shrimp & Spring ME-NH)	NO FALL	NO MAINE	ALL INDICES (Run 1)	WITHOUT Spring ME-NH Index	ONLY Summer Shrimp Index	CURRENTLY-RUNNING INDICES (Summer Shrimp & Spring ME-NH)	NO FALL	NO MAINE
1968	0.17	0.14				0.16	38.68	50.11				41.79
1969	0.36	0.31				0.35	38.93	45.87				40.18
1970	0.35	0.32				0.35	32.86	36.81				32.86
1971	0.43	0.41				0.44	28.63	30.79				27.98
1972	0.55	0.53				0.58	23.45	24.50				22.50
1973	0.64	0.63				0.69	17.48	17.96				16.46
1974	0.86	0.84				0.96	12.10	12.35				11.13
1975	1.11	1.04				1.48	6.91	7.14				5.94
1976	0.33	0.29				0.27	3.13	3.45				1.95
1977	0.11	0.10				0.10	3.12	3.58				2.17
1978	0.00	0.00				0.00	3.86	4.50				2.86
1979	0.07	0.06				0.07	5.30	6.17				4.12
1980	0.04	0.04				0.04	6.73	7.86				5.49
1981	0.11	0.10				0.11	8.74	10.15				7.45
1982	0.14	0.12				0.16	10.52	12.19				9.33
1983	0.12	0.10				0.13	12.24	14.12				11.04
1984	0.22	0.19	0.17	0.26	0.13	0.24	14.42	16.41	18.61	12.11	25.74	13.22
1985	0.27	0.24	0.22	0.32	0.18	0.29	15.28	17.28	18.94	13.01	23.72	14.09
1986	0.31	0.27	0.26	0.36	0.22	0.33	15.34	17.32	18.38	13.07	21.69	14.16
1987	0.37	0.33	0.32	0.44	0.28	0.41	14.85	16.82	17.45	12.60	19.85	13.68
1988	0.22	0.19	0.18	0.26	0.17	0.24	13.53	15.56	16.03	11.37	17.9	12.38
1989	0.22	0.20	0.19	0.26	0.18	0.24	14.40	16.51	16.87	12.36	18.33	13.26
1990	0.31	0.27	0.28	0.36	0.26	0.34	15.16	17.31	17.36	13.21	18.42	14.05
1991	0.24	0.21	0.22	0.28	0.21	0.26	14.59	16.78	16.53	12.72	17.29	13.51
1992	0.22	0.20	0.20	0.25	0.20	0.24	15.10	17.32	16.80	13.33	17.32	14.05
1993	0.13	0.11	0.12	0.14	0.12	0.13	15.87	18.08	17.17	14.14	17.46	14.85
1994	0.15	0.14	0.15	0.17	0.15	0.16	18.26	20.33	18.71	16.37	18.78	17.28
1995	0.33	0.31	0.36	0.38	0.37	0.35	20.31	22.00	19.30	17.88	19.14	19.30
1996	0.59	0.55	0.71	0.74	0.73	0.63	18.86	20.11	16.54	15.84	16.24	17.82
1997	0.61	0.56	0.80	0.86	0.84	0.67	13.67	14.72	10.93	10.44	10.59	12.65
1998	0.45	0.40	0.64	0.74	0.68	0.51	9.92	11.02	7.24	6.57	6.858	8.93
1999	0.21	0.18	0.29	0.37	0.32	0.24	8.50	9.81	5.91	4.87	5.459	7.51
2000	0.25	0.21	0.34	0.46	0.37	0.28	9.30	10.88	6.83	5.25	6.283	8.32
2001	0.13	0.11	0.16	0.23	0.17	0.14	9.72	11.60	7.44	5.14	6.776	8.76
2002	0.04	0.03	0.04	0.06	0.04	0.04	11.49	13.68	9.44	6.28	8.664	10.58
2003	0.08	0.07	0.10	0.13	0.10	0.09	14.73	17.11	12.78	8.92	11.97	13.90
2004	0.11	0.10	0.13	0.17	0.14	0.12	17.76	20.08	15.41	11.26	14.55	17.00
2005	0.12	0.11	0.15	0.19	0.16	0.12	20.57	22.55	17.17	13.21	16.27	19.83
2006	0.09	0.09	0.12	0.15	0.13	0.10	23.36	24.69	18.28	14.89	17.35	22.53
2007	0.18	0.18	0.26	0.29	0.27	0.19	26.89	27.21	19.48	16.98	18.52	25.80
2008	0.17	0.18	0.28	0.31	0.30	0.18	28.16	27.19	18.15	16.52	17.17	26.65
2009	0.08	0.09	0.14	0.15	0.15	0.09	29.48	27.10	16.94	15.98	15.94	27.44
2010	0.19	0.22	0.37	0.37	0.40	0.21	33.49	29.46	18.19	17.90	17.17	30.74
2011	0.17	0.22	0.40	0.39	0.44	0.20	33.90	28.07	15.76	16.07	14.72	30.28
2012							34.65	26.99	13.79	14.50	12.71	30.15

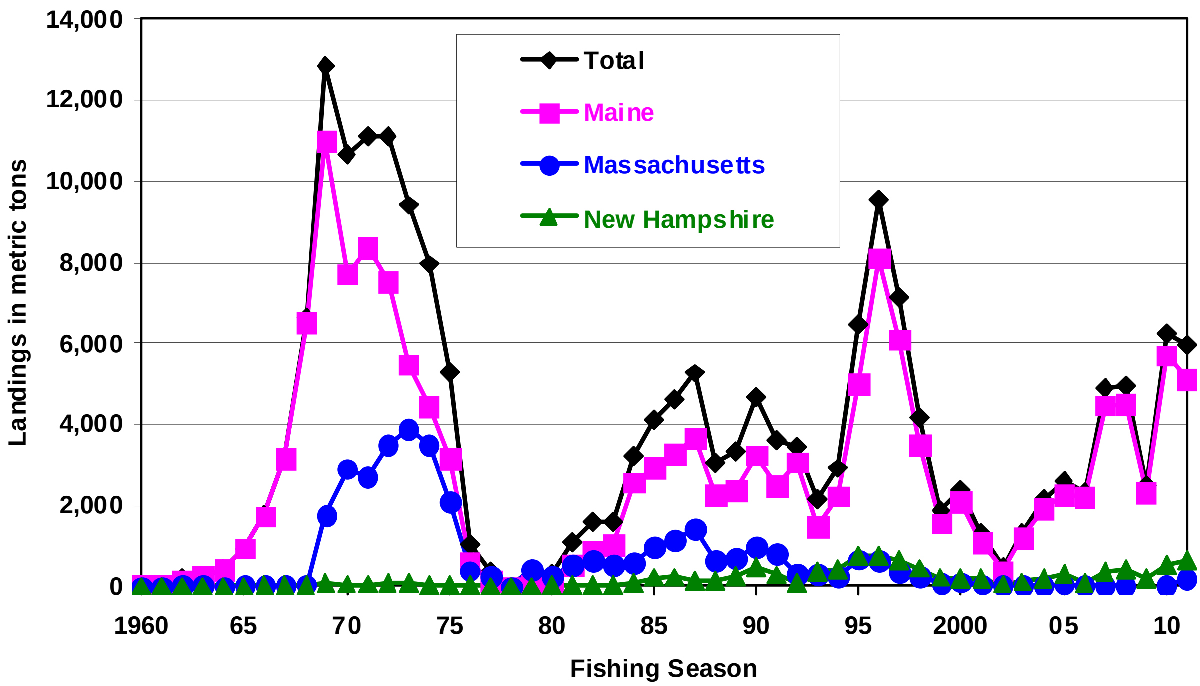
Table 12. Yield and egg production per recruit of Gulf of Maine northern shrimp, for an example fishing mortality F = 0.20, natural mortality M = 0.25, and 1,000 age 0 recruits.

Input Data							Results						
Age	Length (mm)	Transition Rate (% Fem)	Fishery Selectivity	Male wt (g)	Female wt (g)	Fecundity at length	Total N	Male N	Female N	Male Catch	Female Catch	Yield (g)	Egg Production
1	11.17	0	0.033	0.84	1.24	0	774	774	0	4	0	4	0
2	18.43	0	0.230	3.79	4.82	0	575	575	0	31	0	117	0
3	23.50	0.081	0.579	7.87	9.30	1,286	399	367	32	56	0	439	41,581
4	27.04	0.922	0.799	12.00	13.58	1,876	265	21	244	48	4	635	458,156
5	29.51	0.997	0.893	15.60	17.19	2,287	173	0	172	3	35	657	393,661
6	31.23	1.000	0.933	18.50	20.04	2,574	112	0	111	0	26	523	287,027
7	32.43	1.000	1.000	20.72	22.19	2,775	71	0	71	0	18	399	197,299
											total	2,773	1,377,725
											total/recruit	2.773	1,378
											% of max		57.52

Ref. Point	F	YPR	%EPR
F_{max}	0.77	4.25	14.77
$F_{0.1}$	0.46	3.99	29.83
$F_{example}$	0.20	2.77	57.52
$F_{50\%}$	0.25	3.14	50
$F_{40\%}$	0.34	3.62	40
$F_{30\%}$	0.45	3.97	30
$F_{20\%}$	0.63	4.21	20
$F_{10\%}$	0.95	4.21	10

Count per pound

Age	Male	Female
1	540	366
2	120	94
3	58	49
4	38	33
5	29	26
6	25	23
7	22	20



2010 and 2011 data are preliminary.

Figure 1. Gulf of Maine northern shrimp landings by season and state. MA landings are combined with NH landings in 2009 to preserve confidentiality.

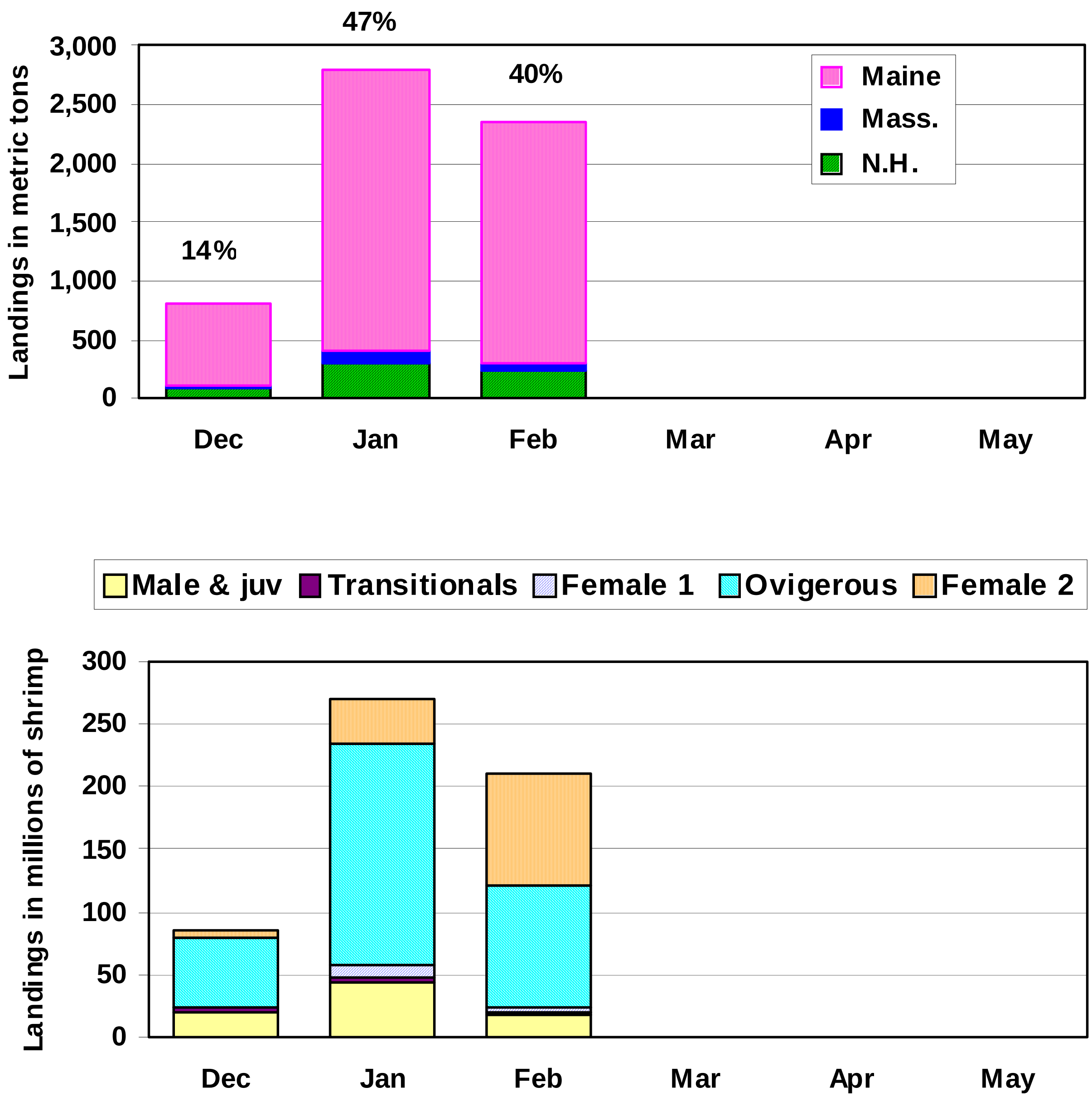


Figure 2. Gulf of Maine northern shrimp landings by month in the 2011 season (preliminary data). Landings are in metric tons by state (above), and in millions of shrimp by development stage (below).

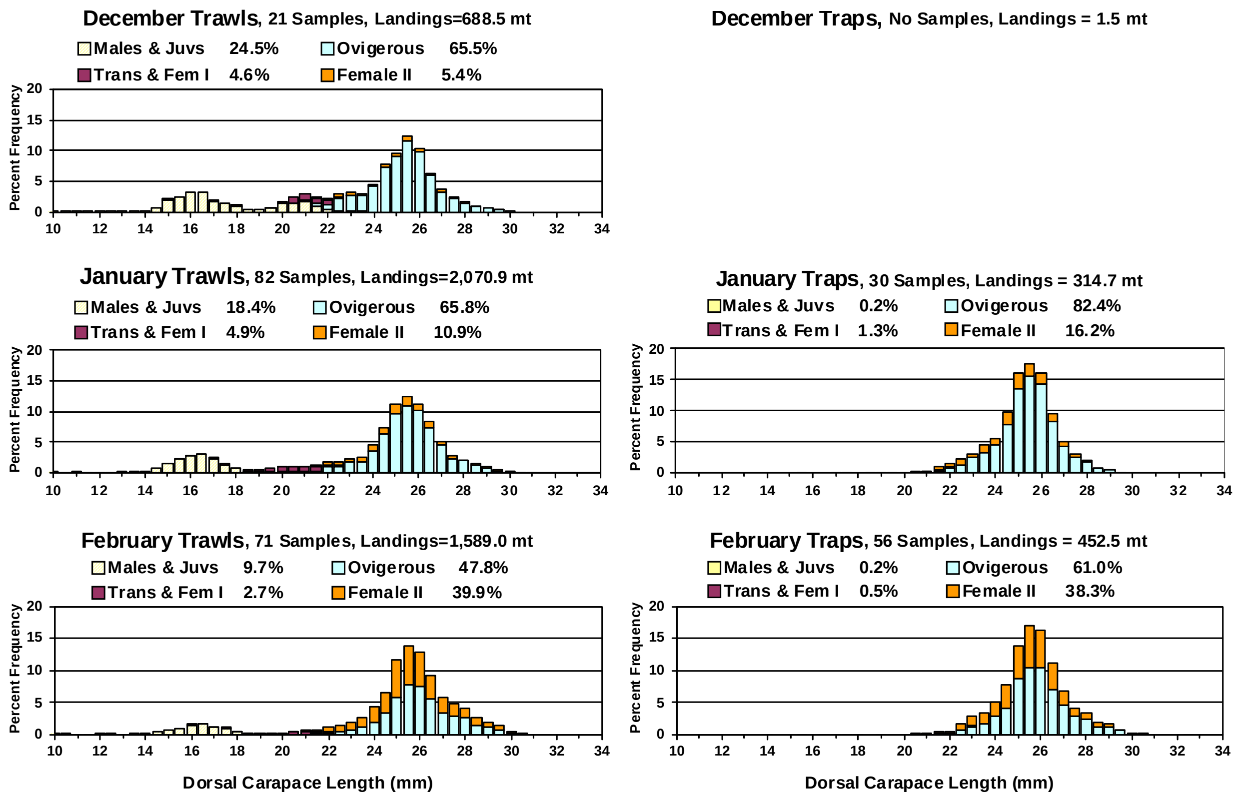


Figure 3. Relative length-frequency distributions from samples of Maine northern shrimp catches during the 2011 season by month, trawl catches on left and trap catches on right. Landings are preliminary.

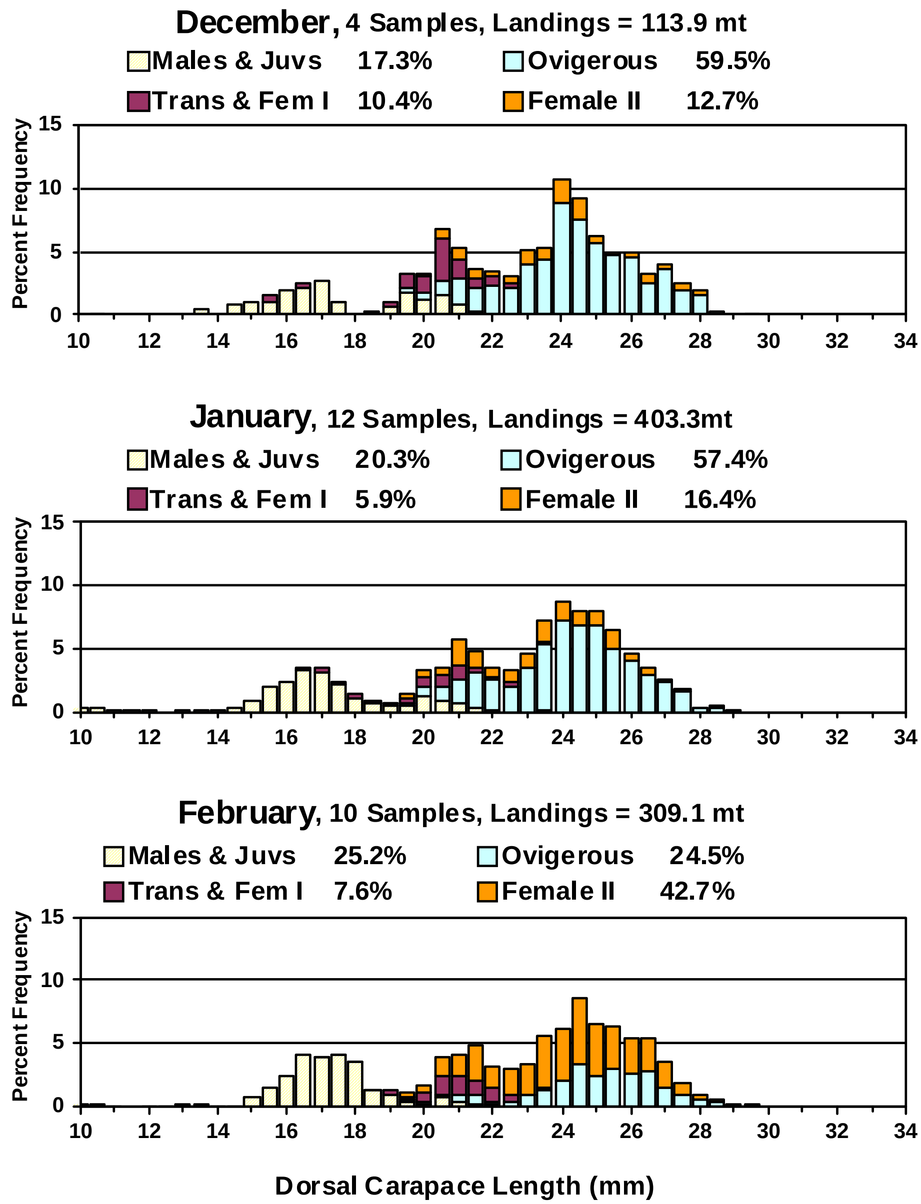


Figure 4. **Relative length-frequency distributions from samples of Massachusetts and New Hampshire northern shrimp catches during the 2011 season by month. Landings are preliminary.**

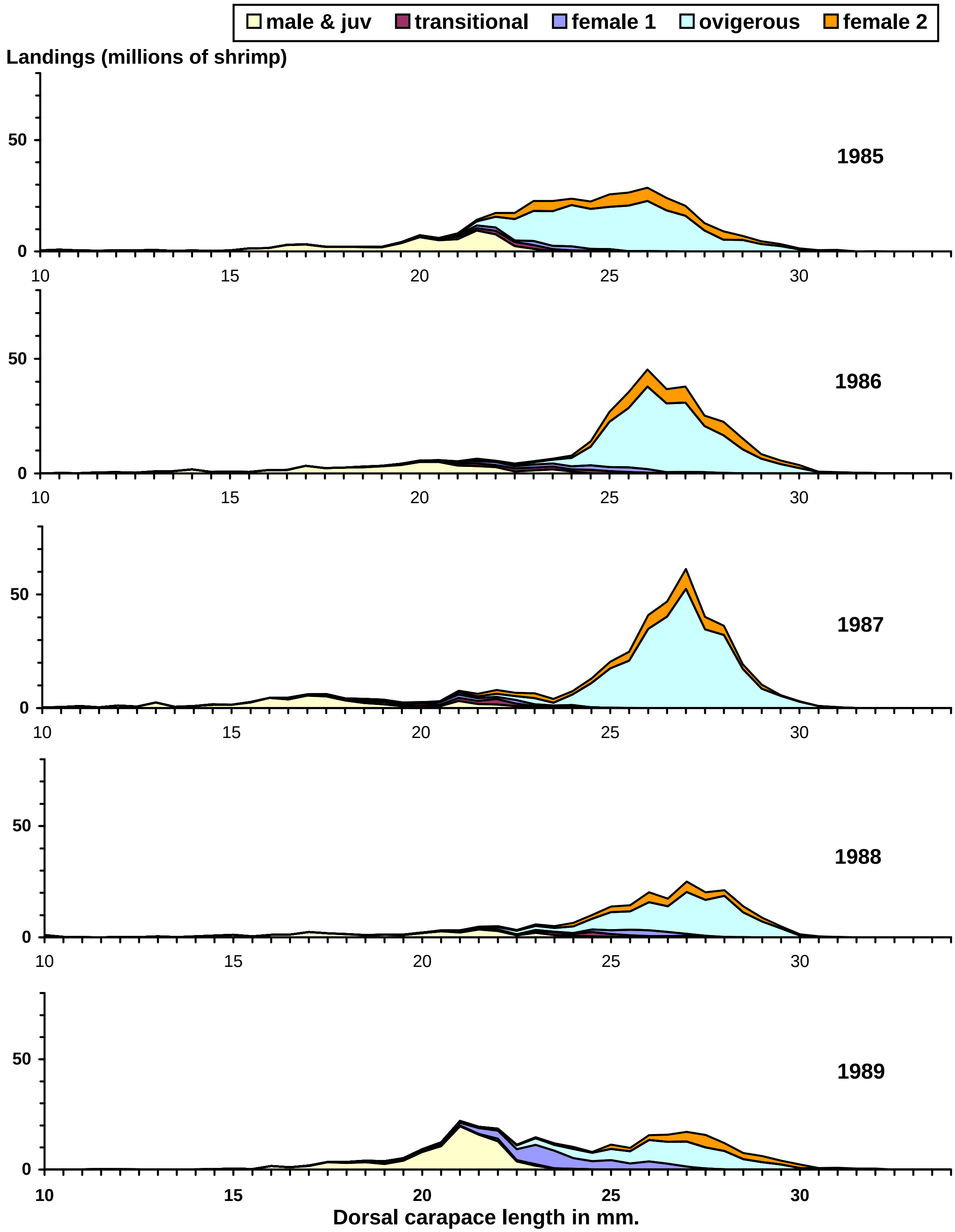


Figure 5. Gulf of Maine northern shrimp landings in estimated numbers of shrimp, by length, development stage, and fishing season. Landings are preliminary throughout.

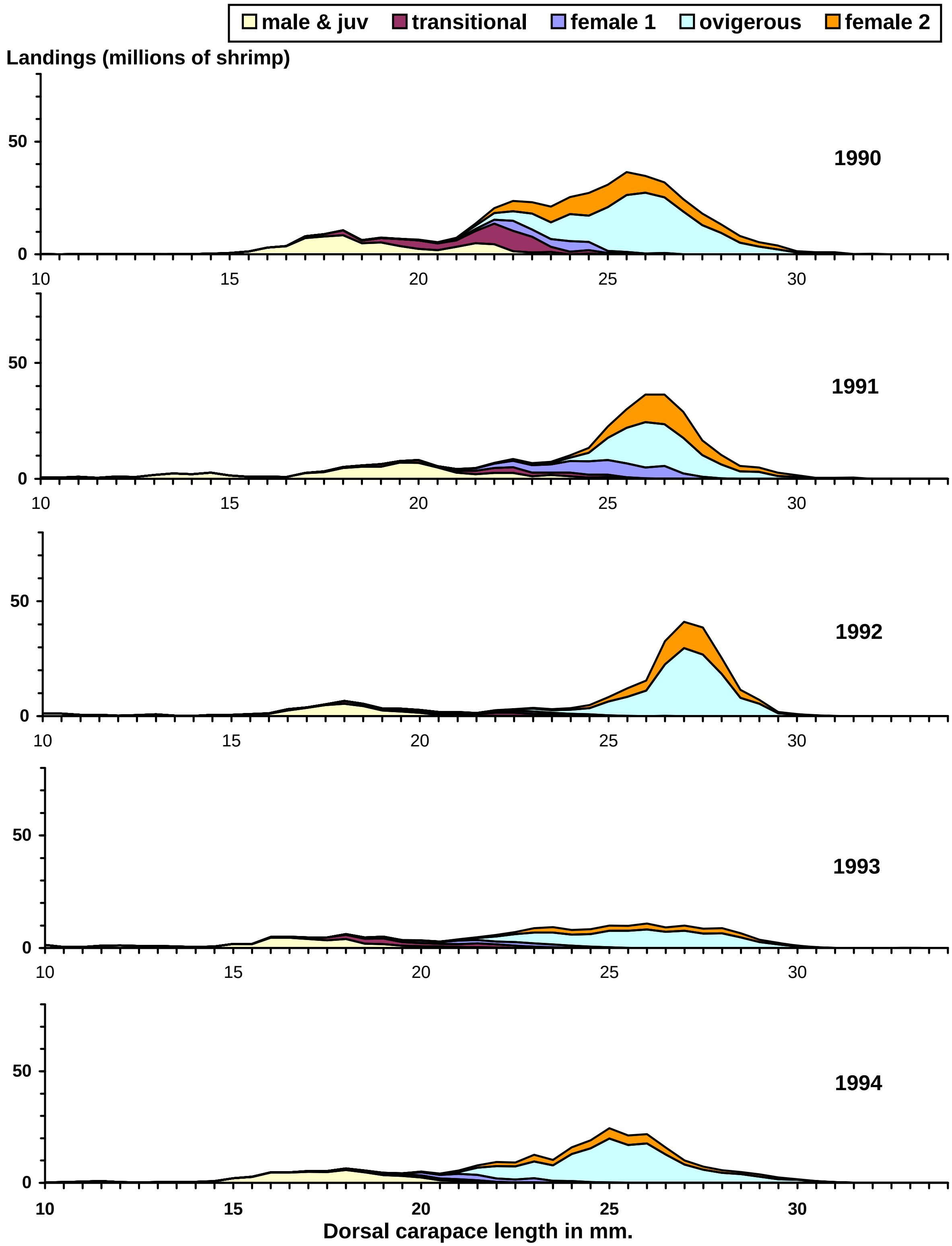


Figure 5 continued – Preliminary landings in estimated numbers of shrimp.

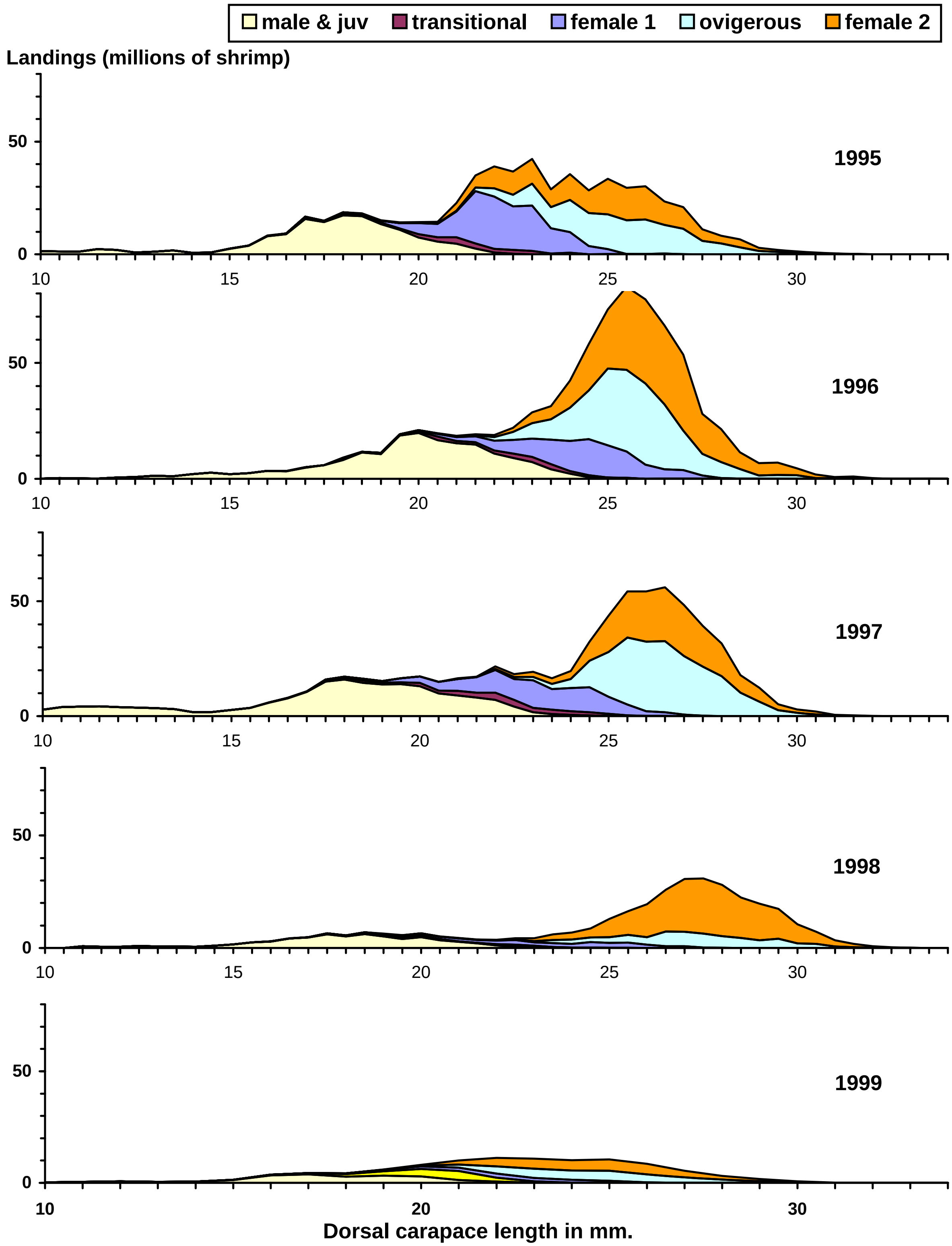


Figure 5 continued – Preliminary landings in estimated numbers of shrimp.

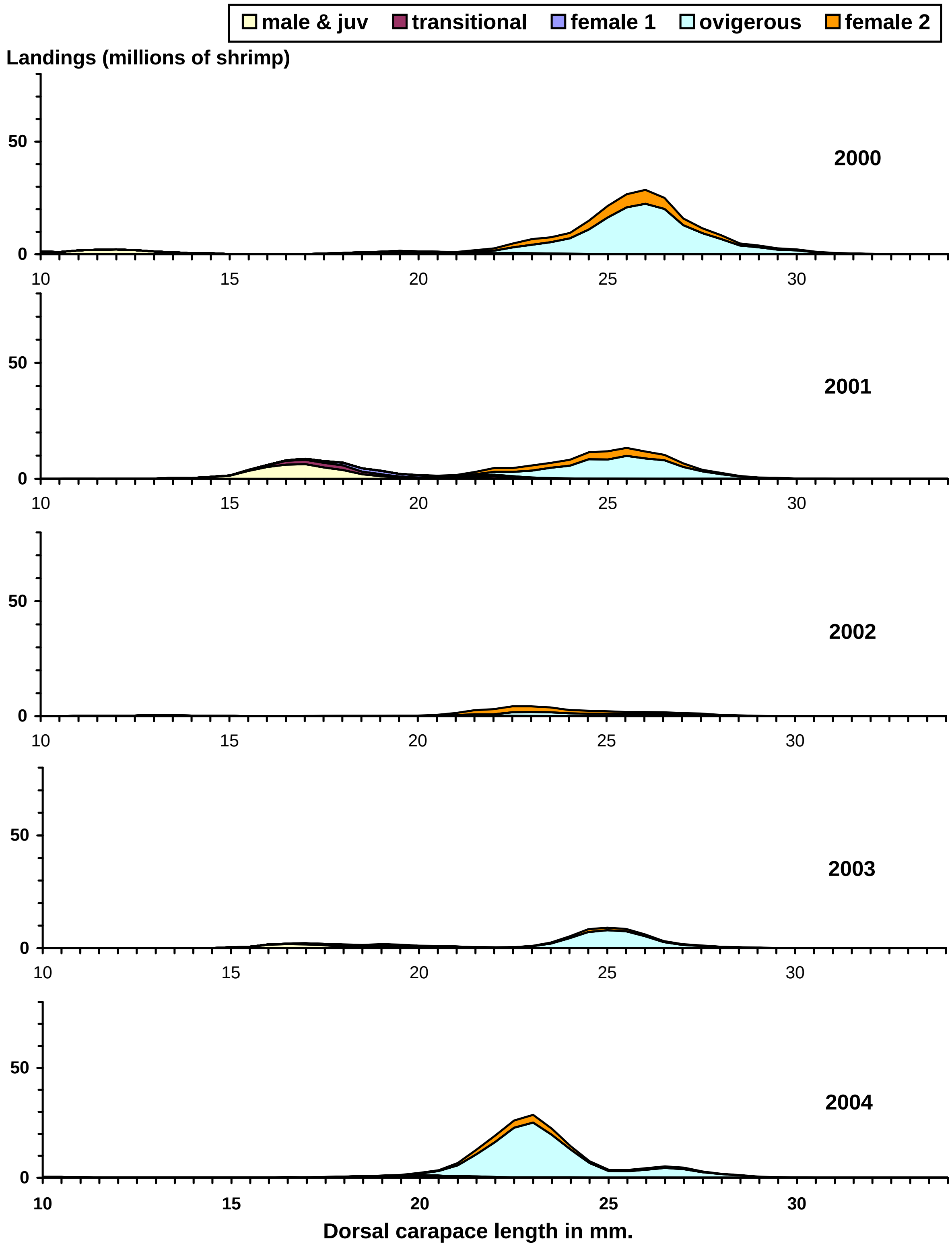


Figure 5 continued – Preliminary landings in estimated numbers of shrimp.

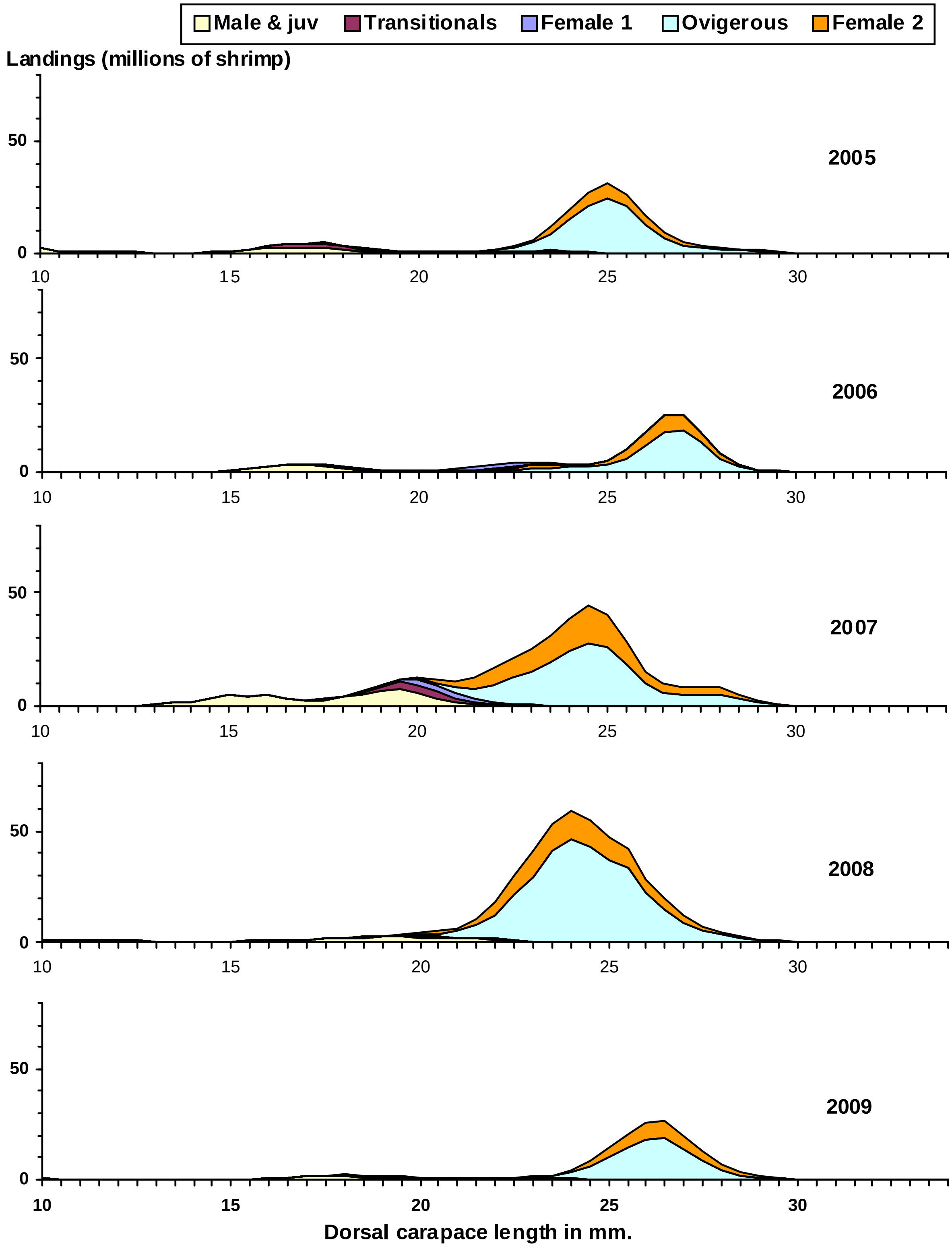


Figure 5 continued – Preliminary landings in estimated numbers of shrimp.

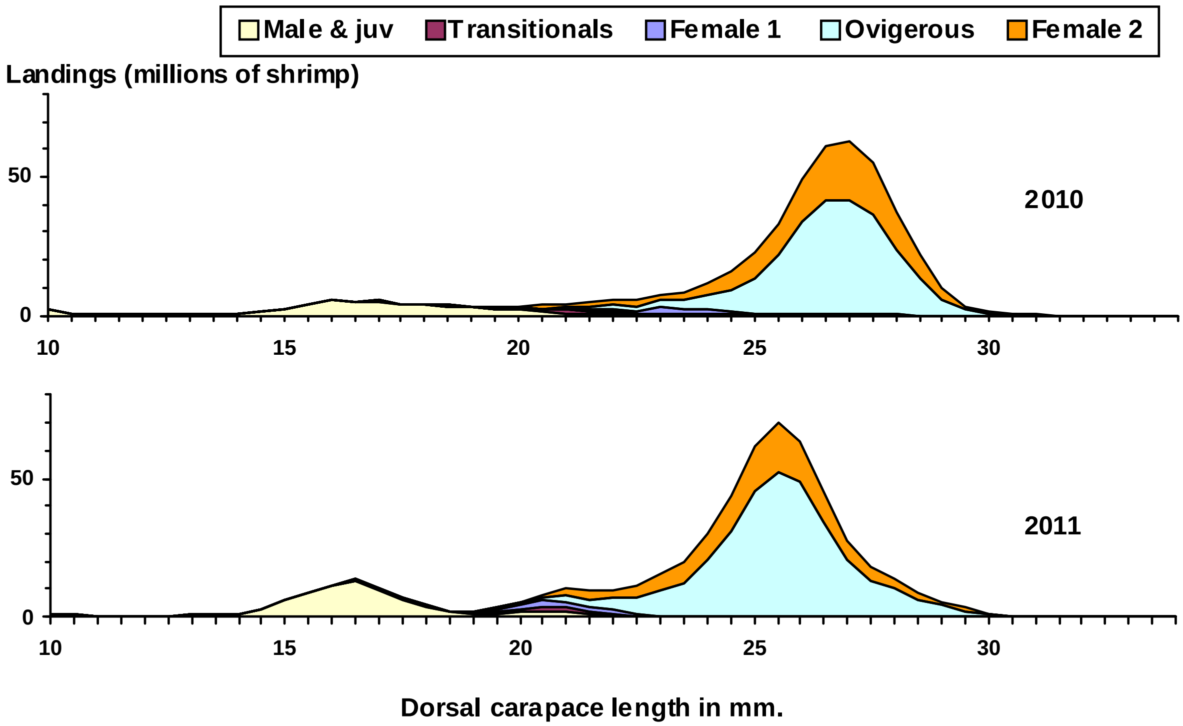
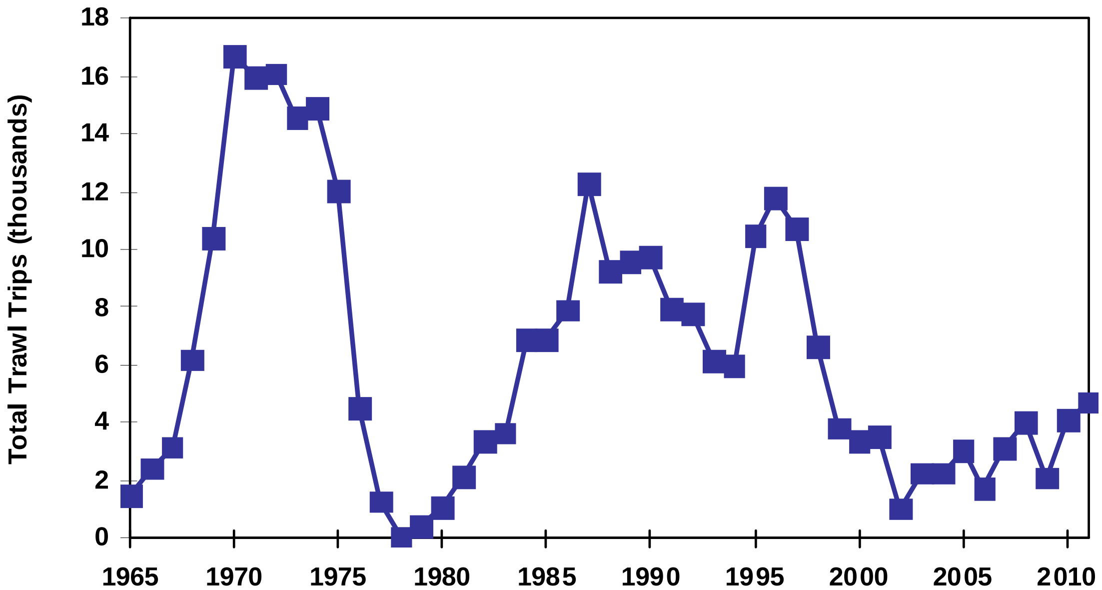


Figure 5 continued – Preliminary landings in estimated numbers of shrimp.



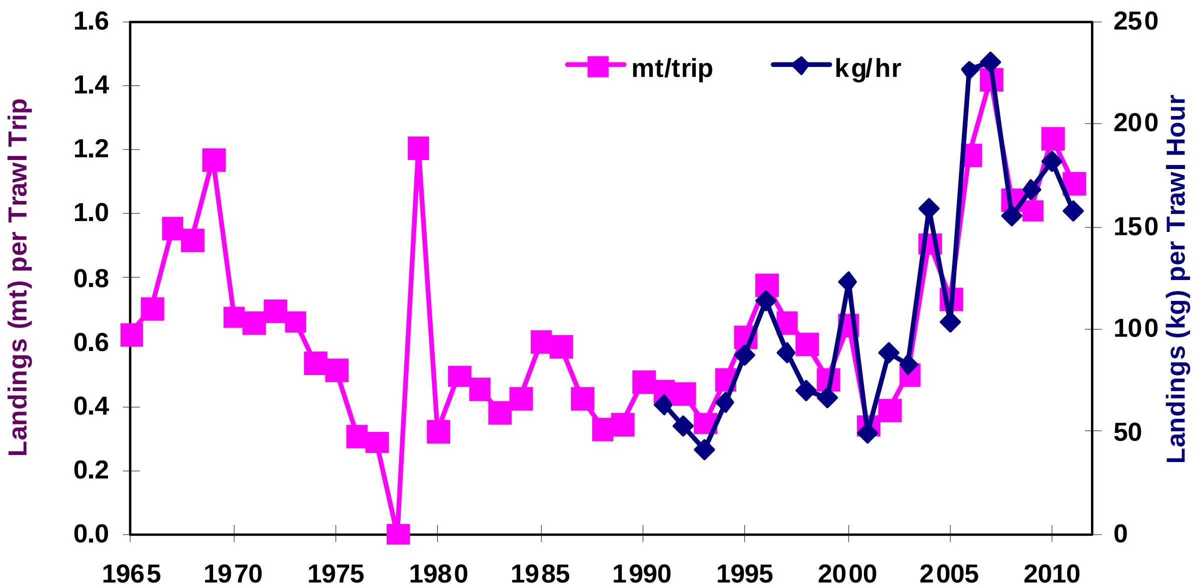
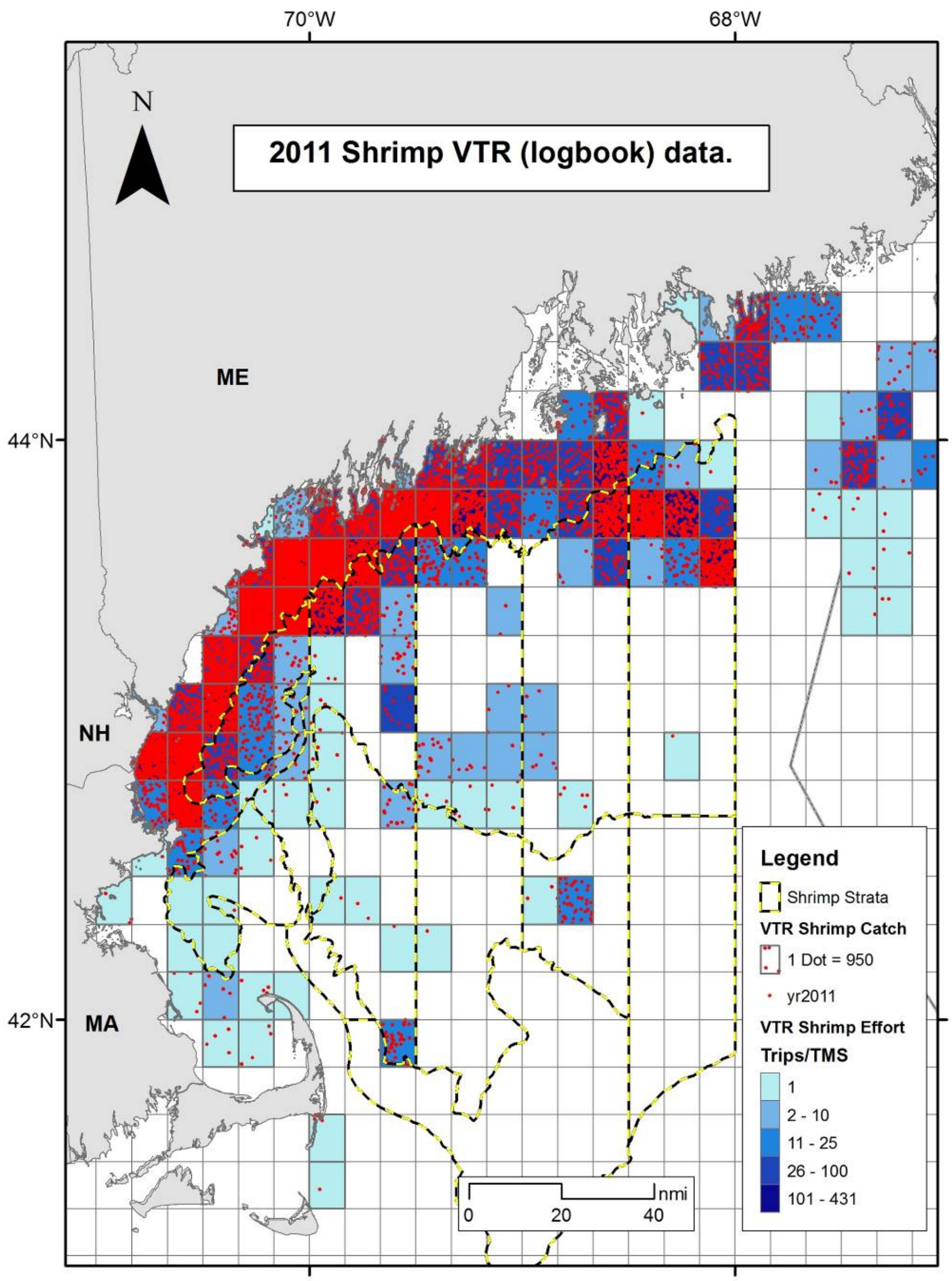


Figure 6. Nominal fishing effort (trawl trips) (above) and catch per unit effort (below), in the Gulf of Maine northern shrimp fishery by season. 2010 and 2011 data are preliminary.



Dot density symbols (red dots) were used to display pounds caught per Ten Minute Square (TMS). Each dot represents 950 lbs, the median value of pounds landed per trip across all years, therefore squares with more dots reported higher landings. Effort or number of trips per TMS are displayed in the background as the blue color palette.

Figure 7. Pounds caught and numbers of trips during the 2011 northern shrimp fishing season by 10-minute-square. Each red dot represents 950 lbs caught; locations of dots within squares are random and do not reflect the actual location of the catch. Number of trips is indicated by the blue palette for the squares. From preliminary state and federal harvester logbook (VTR) data.

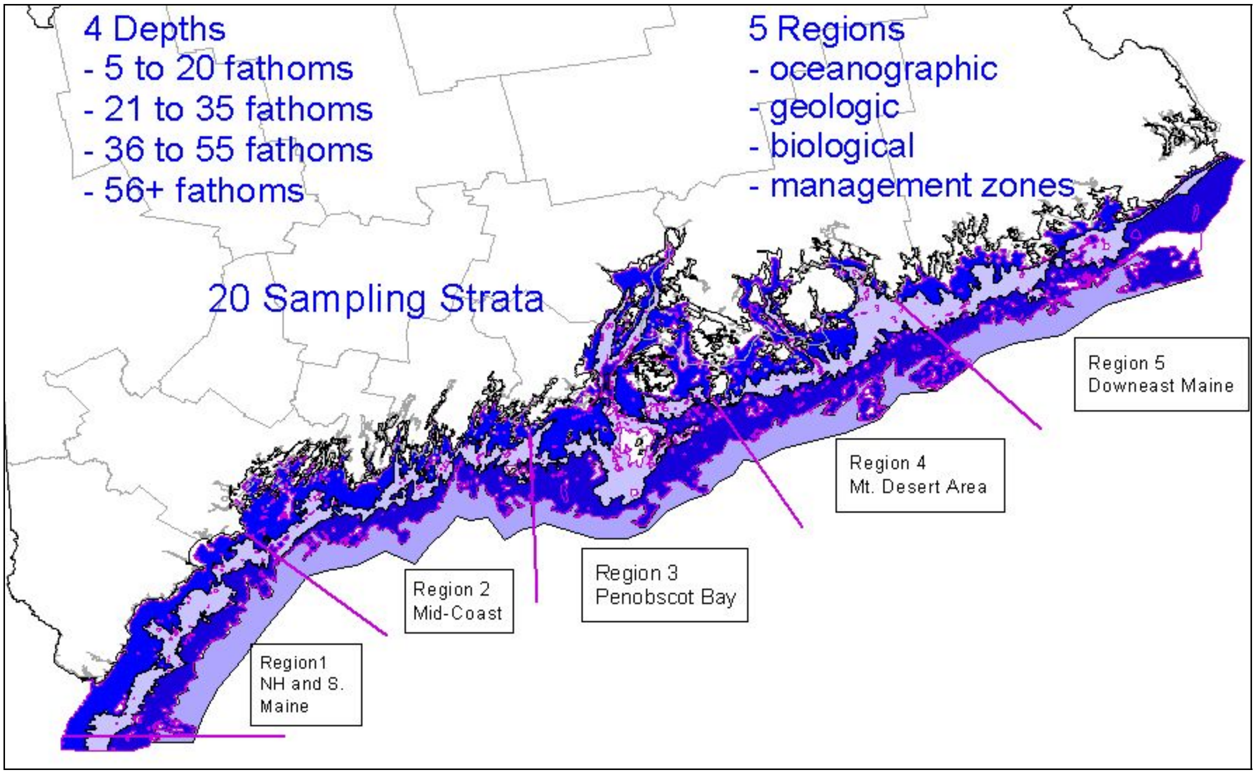


Figure 8a. Maine-New Hampshire inshore trawl survey depths and regions.

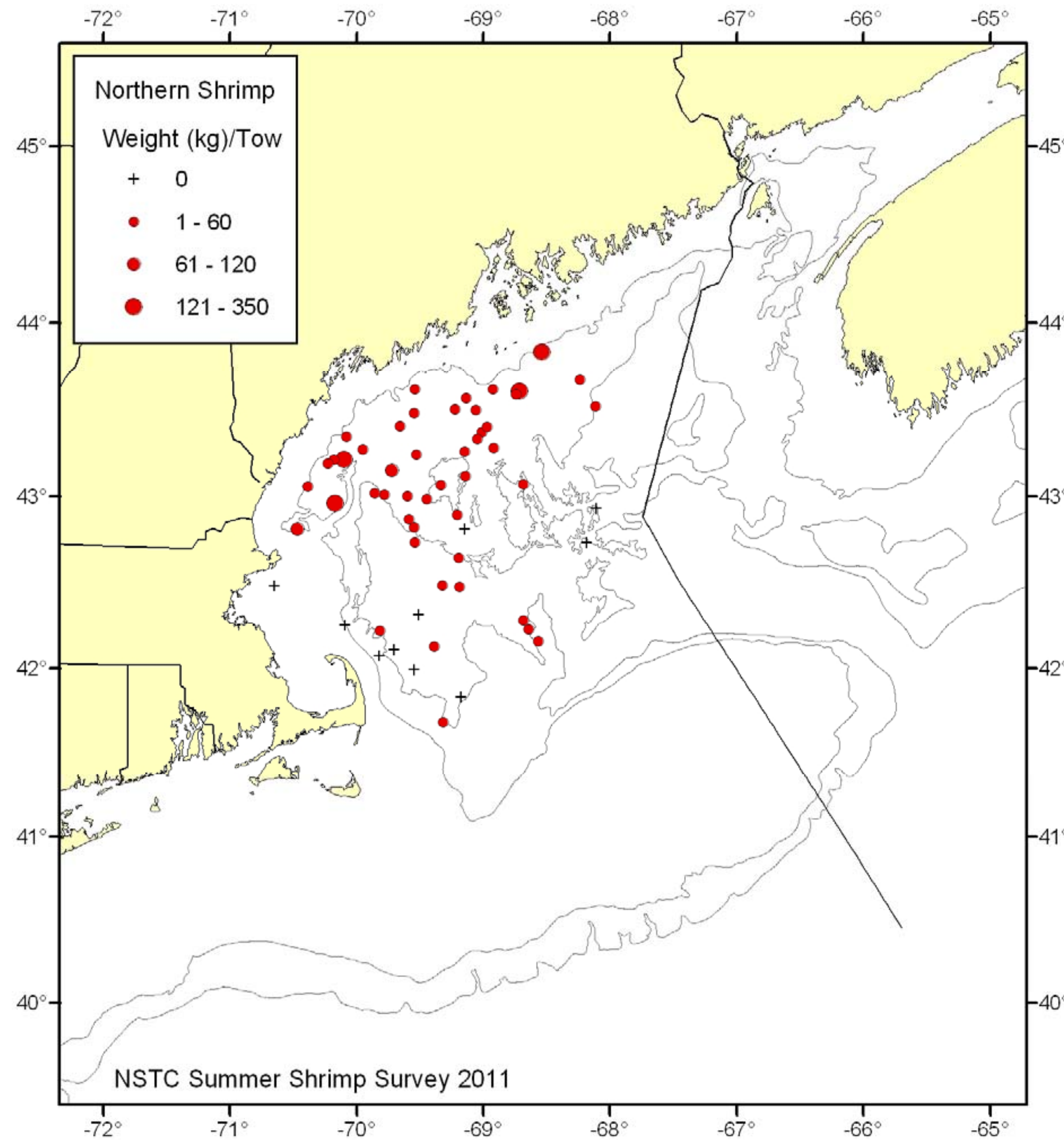


Figure 8b. State/federal summer northern shrimp survey aboard the *R/V Gloria Michelle*, July 10 – August 6, 2011, with survey sites and shrimp catches in kg/tow.

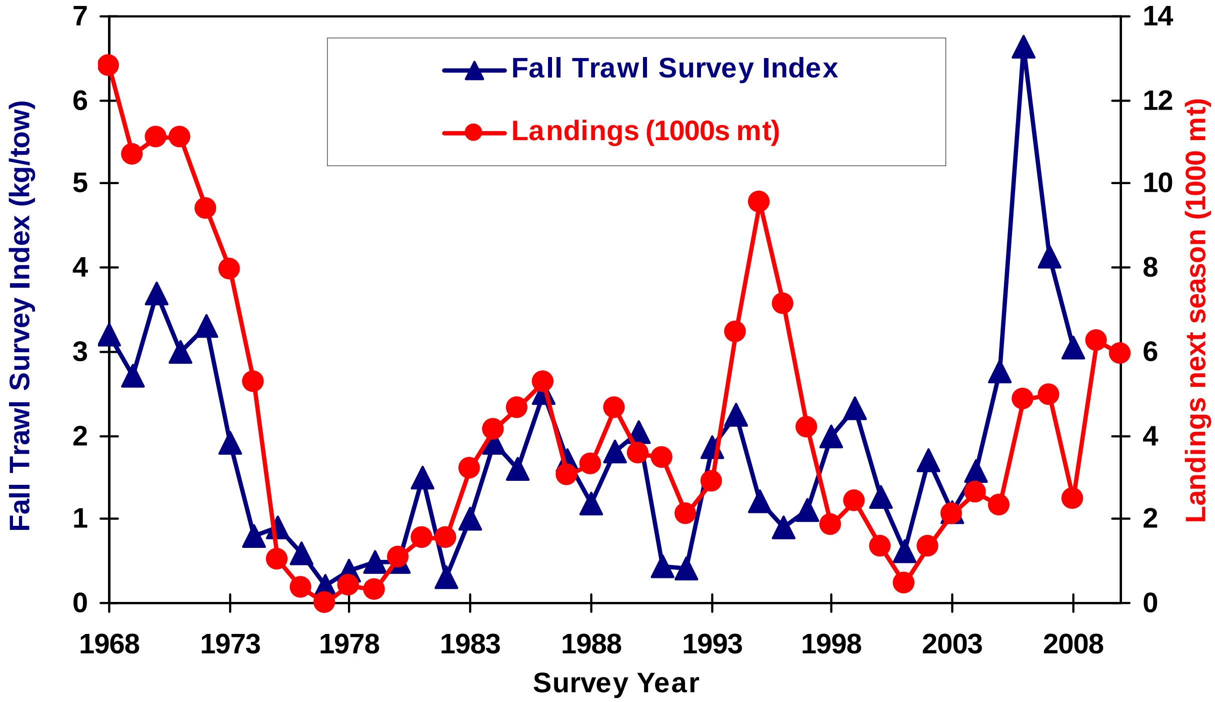
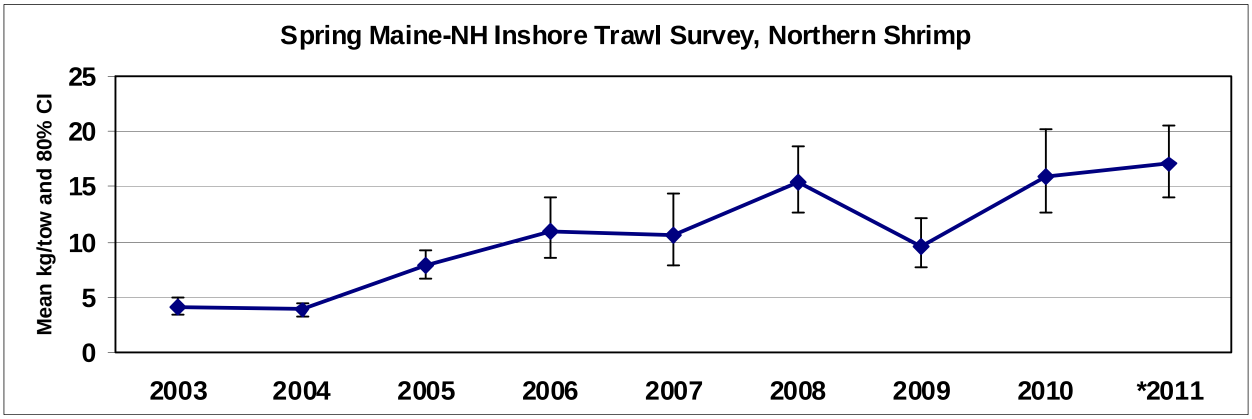


Figure 9. **Fall trawl survey index (through 2008) and Gulf of Maine northern shrimp landings the following season.**



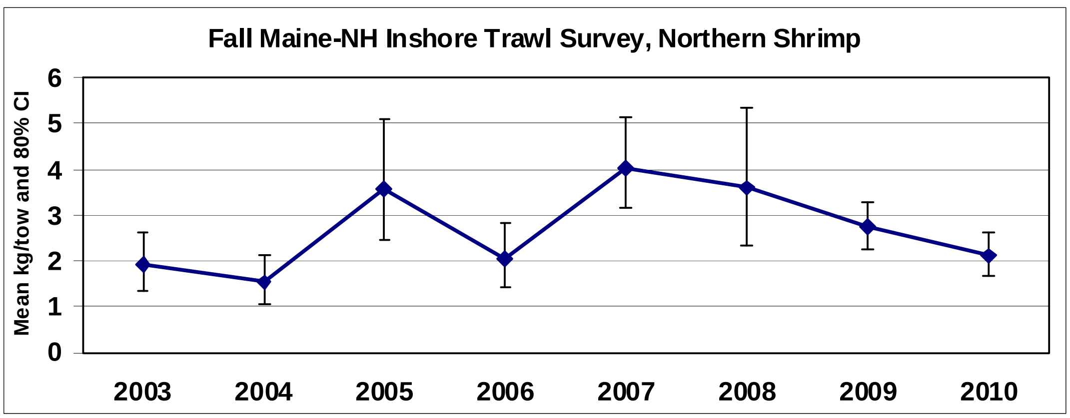


Figure 10. Maine-New Hampshire inshore trawl survey northern shrimp biomass indices, spring above and fall below, with 80% confidence intervals. *2011 data are preliminary.

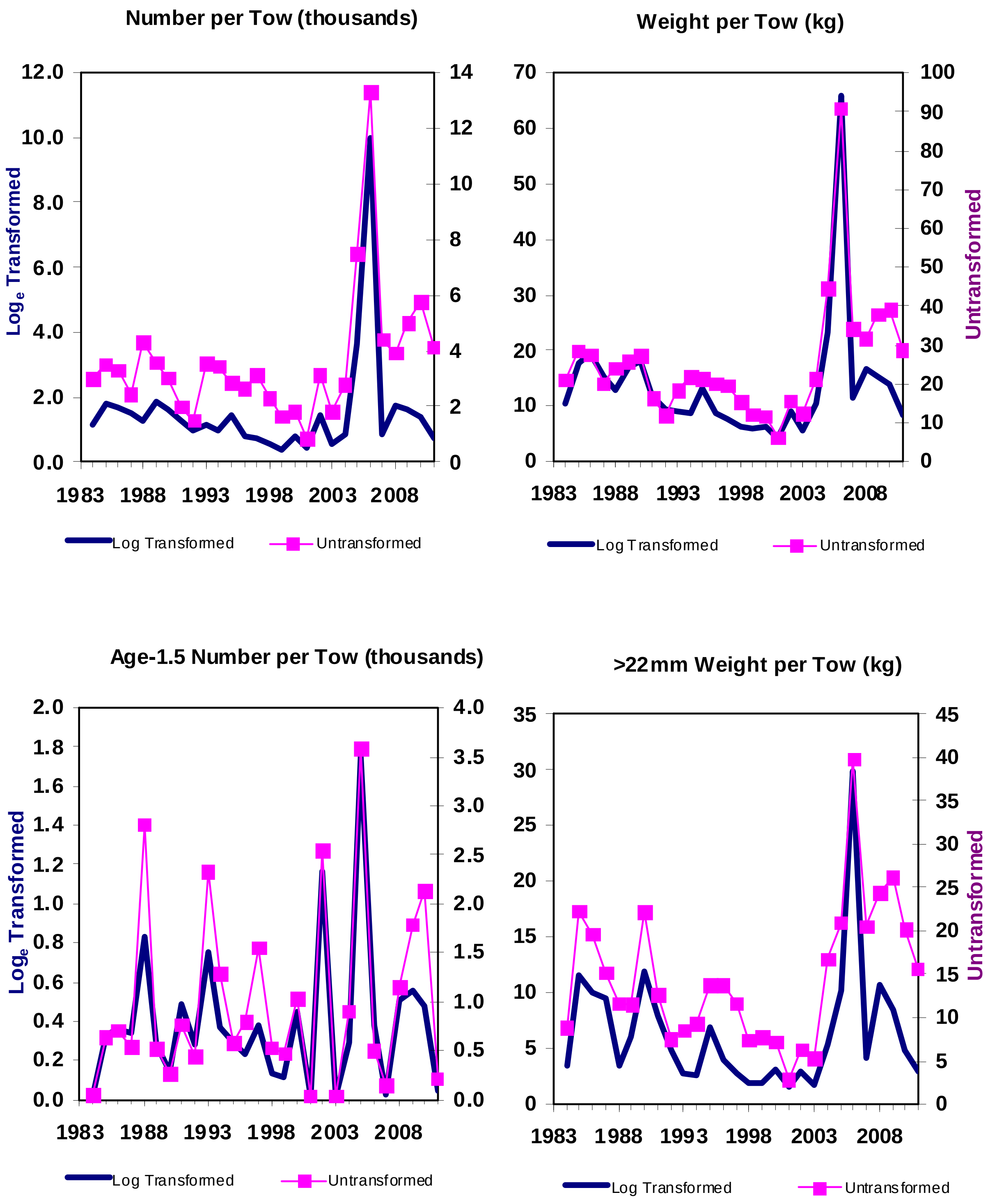


Figure 11. Gulf of Maine northern shrimp summer survey indices of abundance (left) and biomass (right), by survey year.

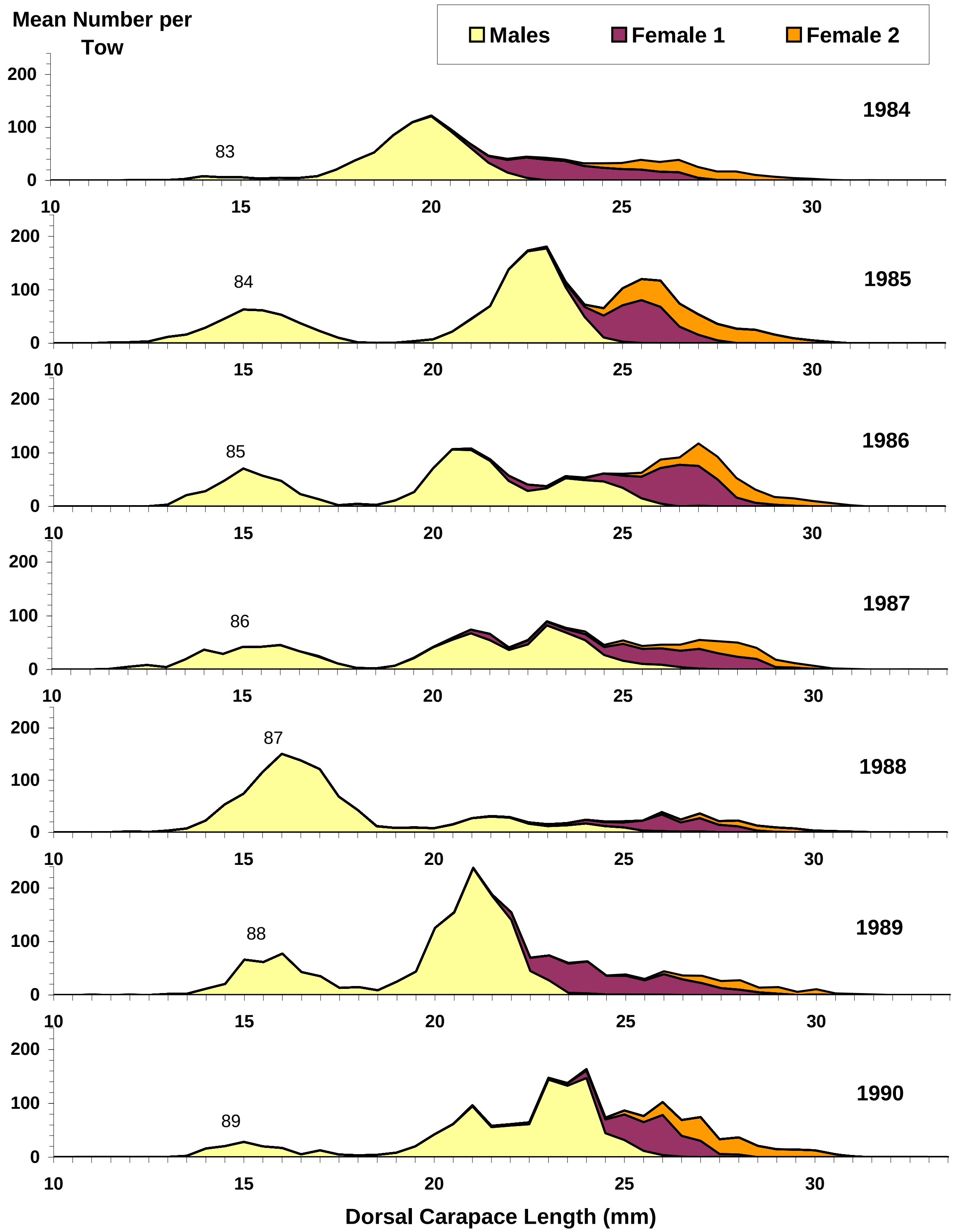


Figure 12. Gulf of Maine northern shrimp summer survey mean catch per tow by year, length, and development stage. Two-digit years are year class at assumed age 1.5.

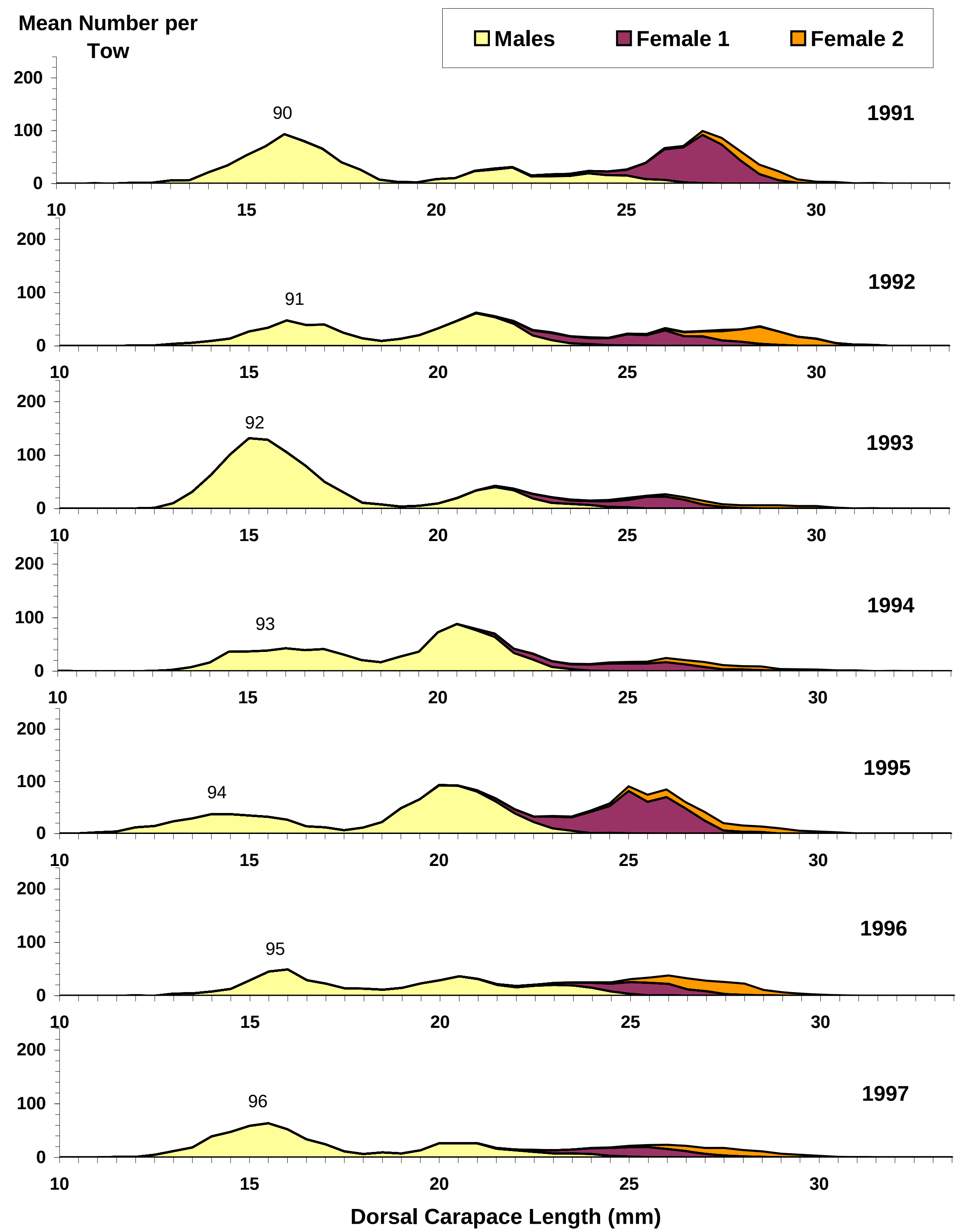


Figure 12 continued – summer survey.

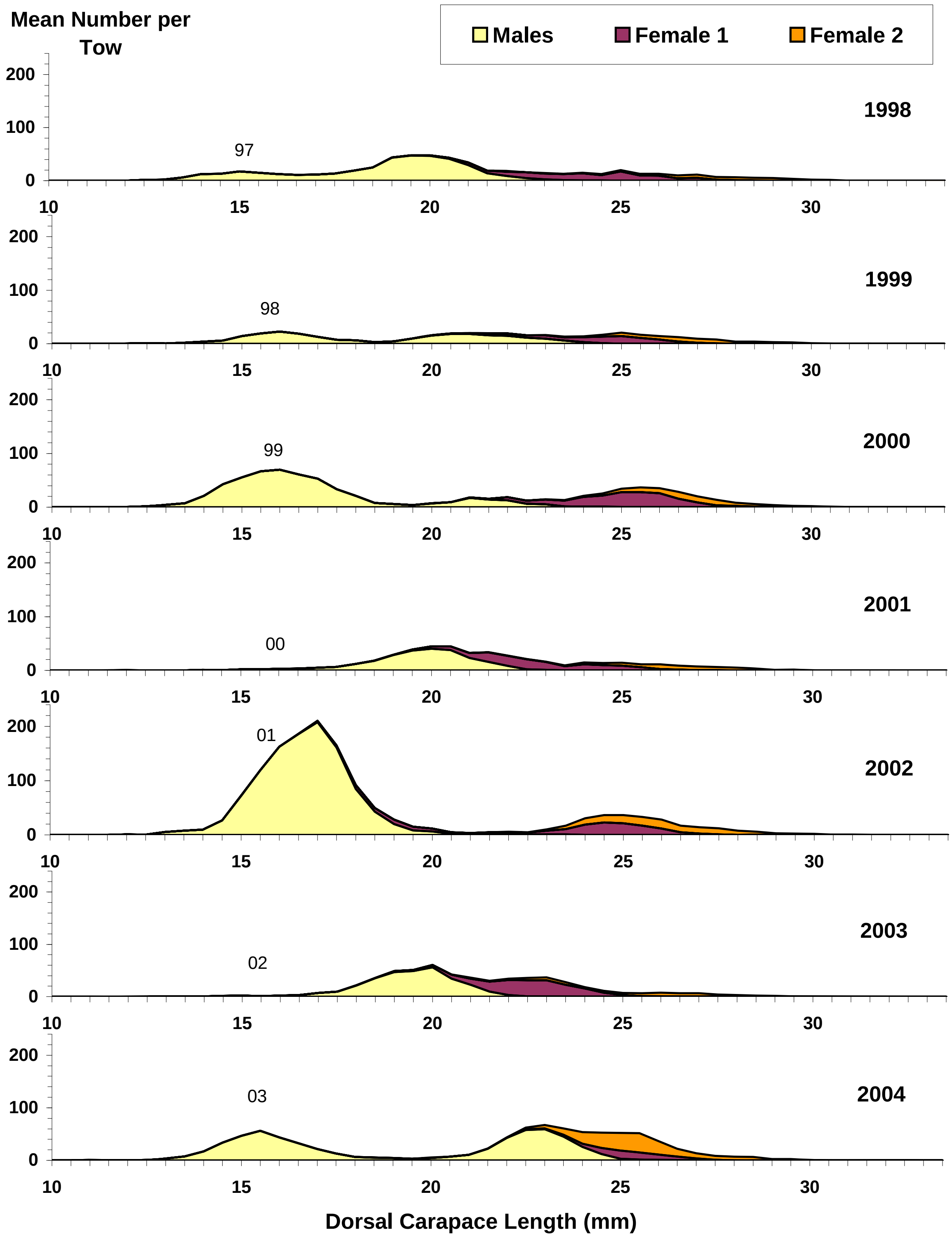


Figure 12 continued – summer survey.

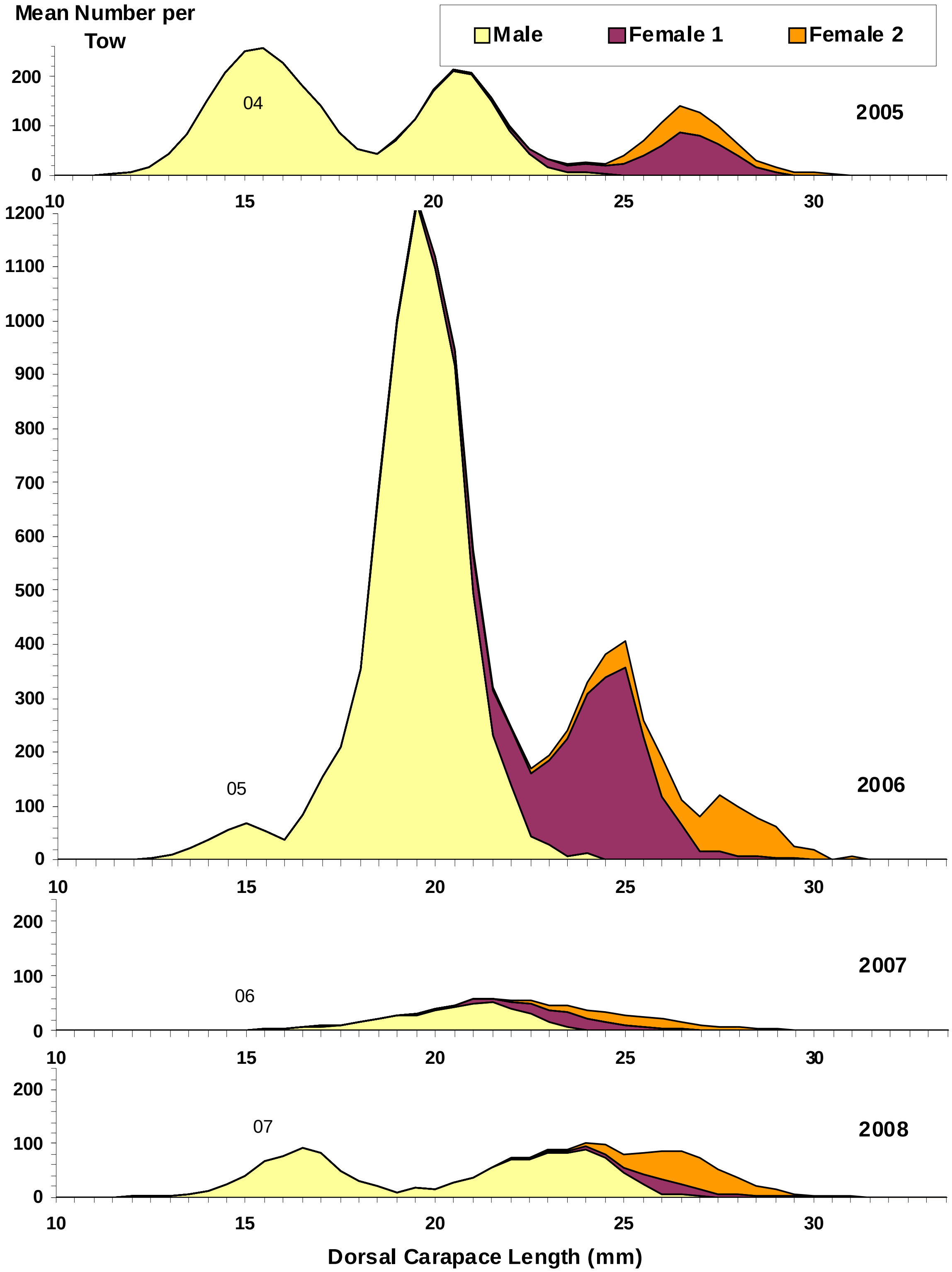


Figure 12 continued – summer survey.

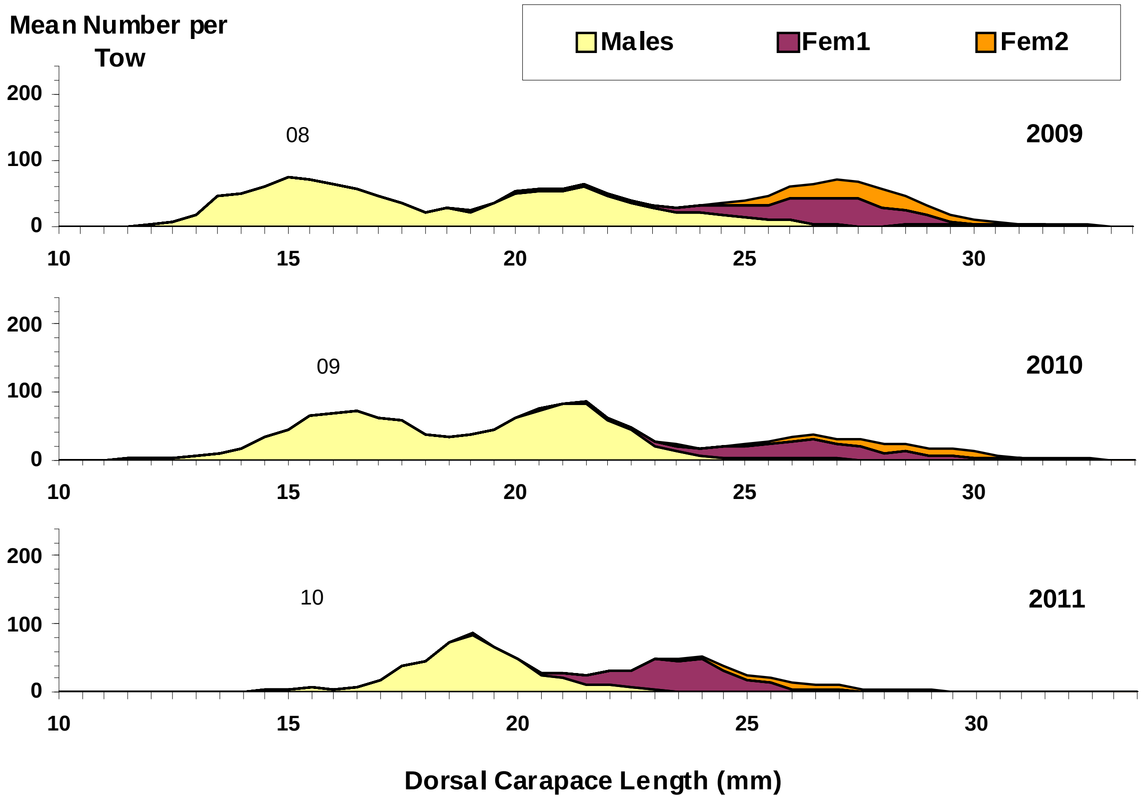


Figure 12 continued – summer survey.

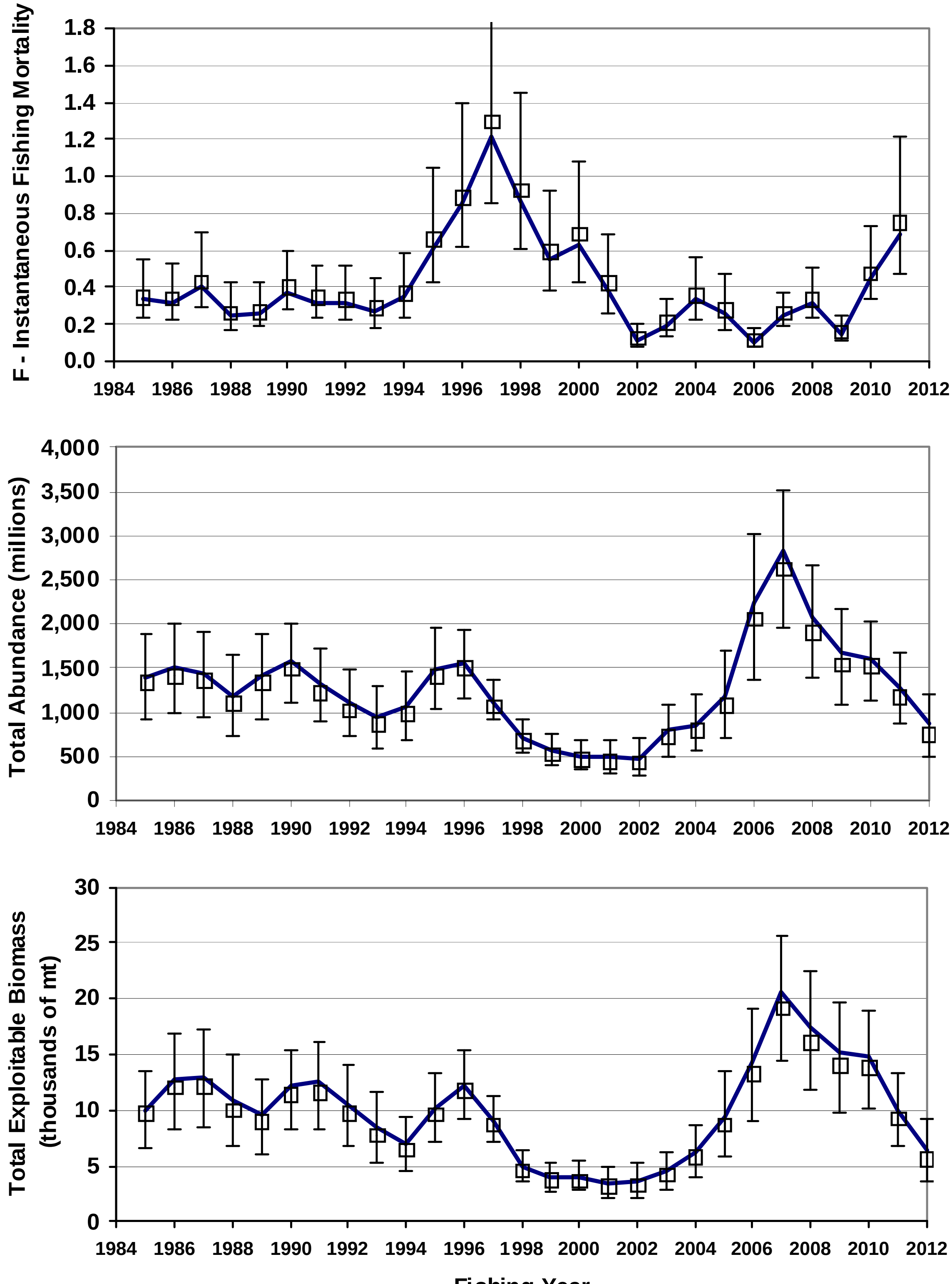


Figure 13. Fishing mortality, exploitable abundance, and exploitable biomass of Gulf of Maine northern shrimp as estimated by CSA, with least squares estimates and bootstrapped medians (square symbols) with 80% confidence intervals.

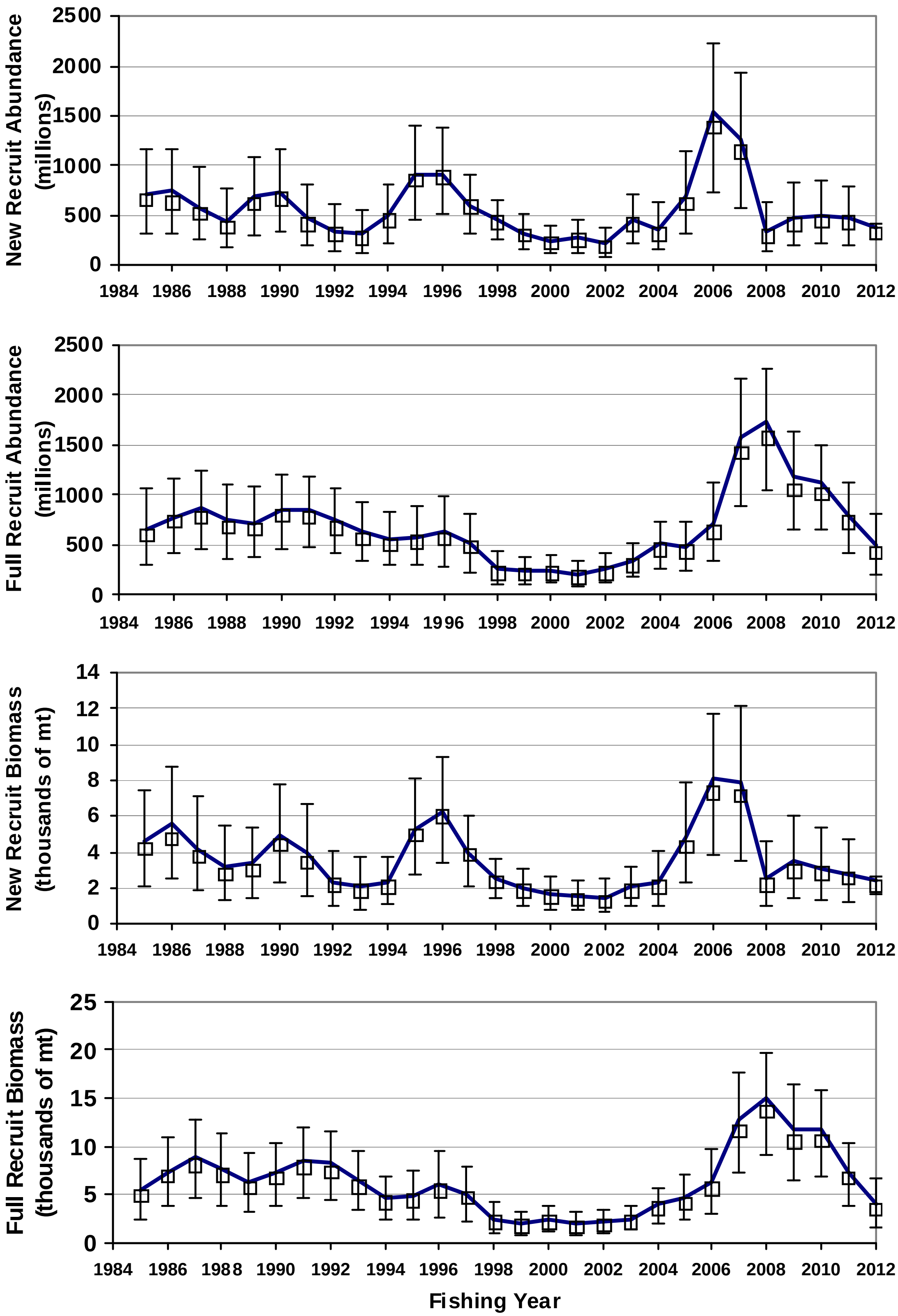
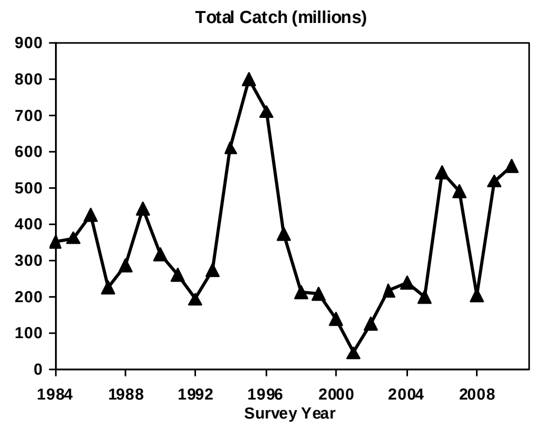


Figure 13 continued – CSA estimates.

Input Data from Summer Surveys and Landings			
Survey Year*	Indices of Abundance		Total Catch Millions*
	New Recruits	Full Recruits	
1984	447.6	479.1	352.65
1985	611.5	913.6	363.25
1986	533.3	848.5	427.00
1987	482.9	766.9	228.43
1988	459.8	387.7	286.21
1989	701.1	817.9	444.01
1990	511.5	907.5	320.20
1991	374.3	612.1	262.33
1992	313.6	444.4	194.75
1993	410.2	320.8	272.74
1994	368.6	364.3	610.99
1995	485.8	653.3	798.27
1996	257.7	348.6	710.95
1997	257.3	267.1	373.43
1998	217.1	226.6	215.12
1999	137.4	174.6	209.28
2000	276.3	288.2	138.73
2001	171.8	196.4	46.78
2002	550.6	372.9	126.26
2003	222.9	229.9	217.22
2004	292.7	405.9	238.92
2005	1295.2	1231.7	202.34
2006	3878.3	4024.4	542.15
2007	323.2	421.0	490.76
2008	561.7	847.3	207.30
2009	514.3	722.7	520.16
2010	490.9	538.9	561.40
2011	292.9	316.2	

Results			
Exploitable Stock Size Estimates millions at time of survey		Fishing Mortality All sizes	Total Mortality Z all sizes
Recruits	Full Recruits		
715.9	663.5	0.34	0.59
749.6	766.0	0.31	0.56
573.8	862.7	0.41	0.66
436.5	746.0	0.24	0.49
692.8	720.9	0.26	0.51
738.4	850.4	0.38	0.63
477.2	849.6	0.32	0.57
347.6	753.3	0.31	0.56
310.4	627.9	0.27	0.52
492.5	560.3	0.34	0.59
910.3	581.6	0.61	0.86
915.9	630.8	0.85	1.10
598.1	514.1	1.22	1.47
461.4	255.6	0.86	1.11
327.7	235.5	0.56	0.81
245.7	251.4	0.63	0.88
288.2	205.4	0.38	0.63
219.3	263.2	0.12	0.37
465.2	334.7	0.20	0.45
348.6	512.3	0.33	0.58
696.7	480.6	0.26	0.51
1535.1	707.7	0.11	0.36
1256.8	1569.0	0.24	0.49
341.4	1725.9	0.31	0.56
485.0	1180.8	0.15	0.40
490.1	1115.5	0.45	0.70
467.8	796.8	0.68	0.93
370.9	497.6		

* Survey Year data are applied to the following Fishing Year



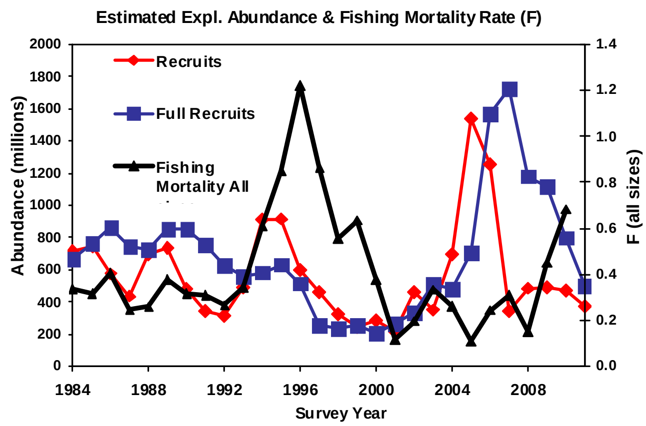


Figure 14a. Catch-Survey model (CSA) input data and results.

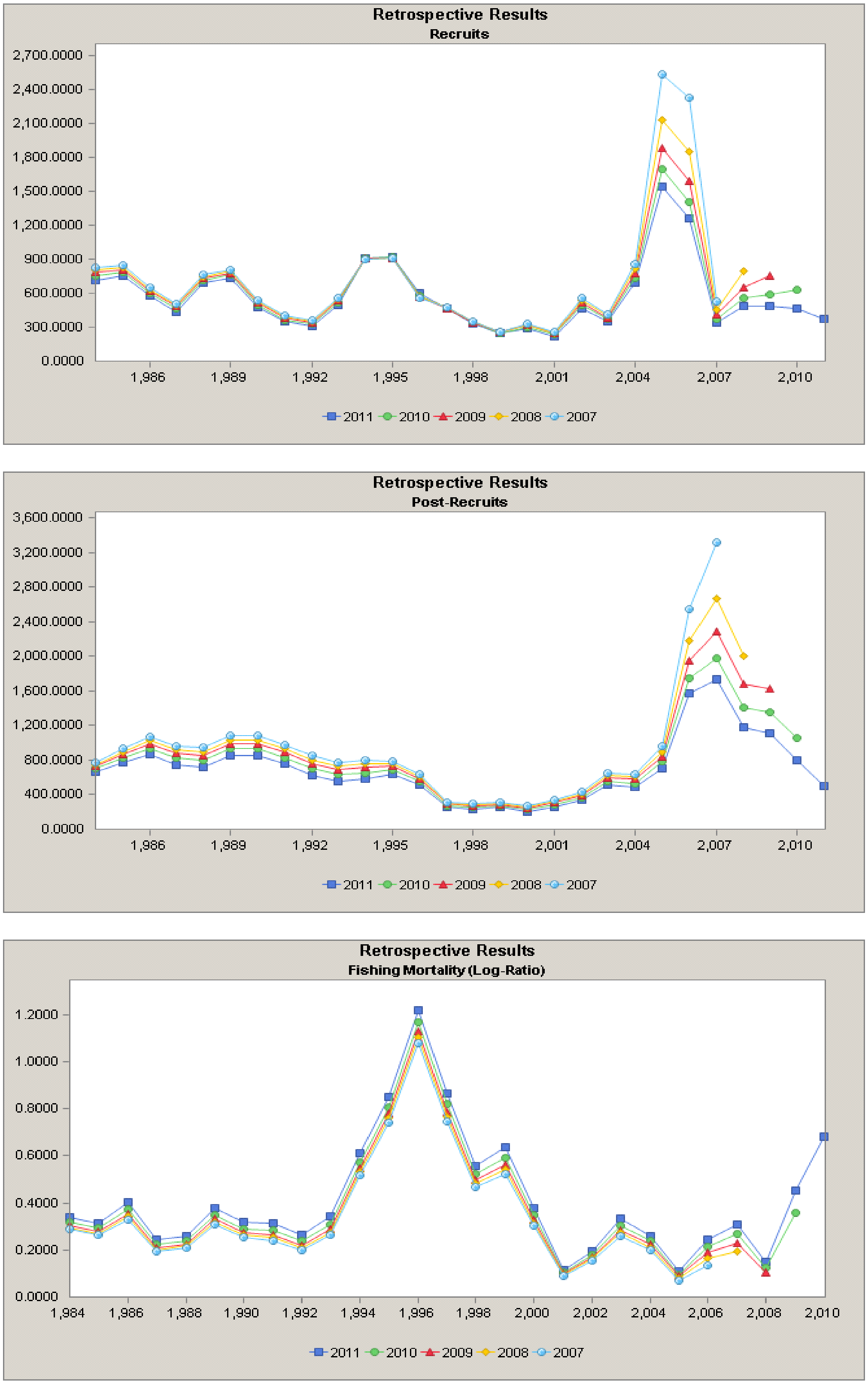
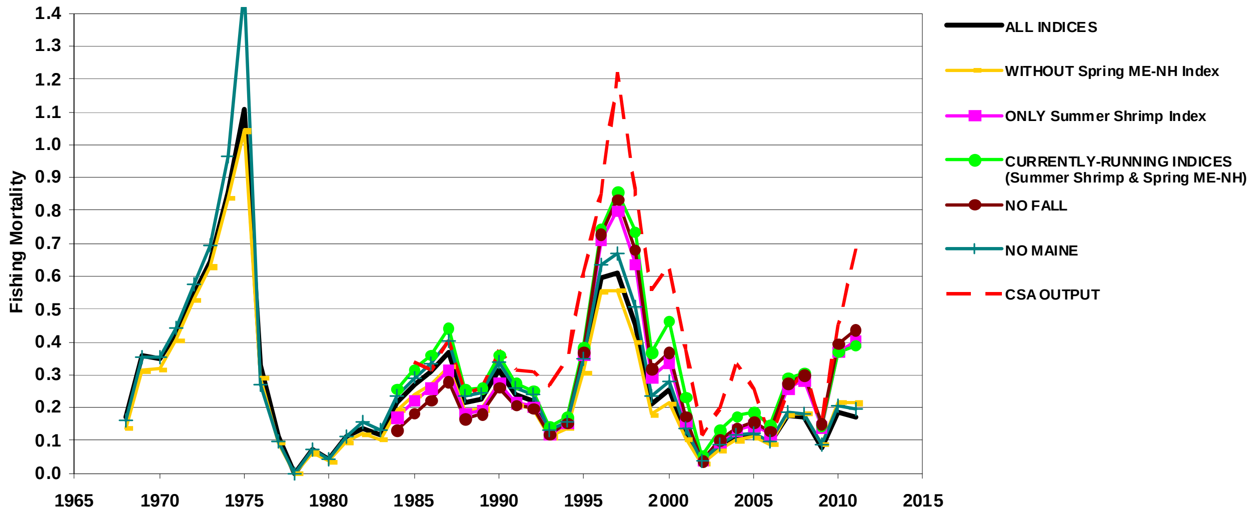


Figure 14b. Catch-Survey model (CSA) retrospective results, successively adding additional years' data (2008-2011)



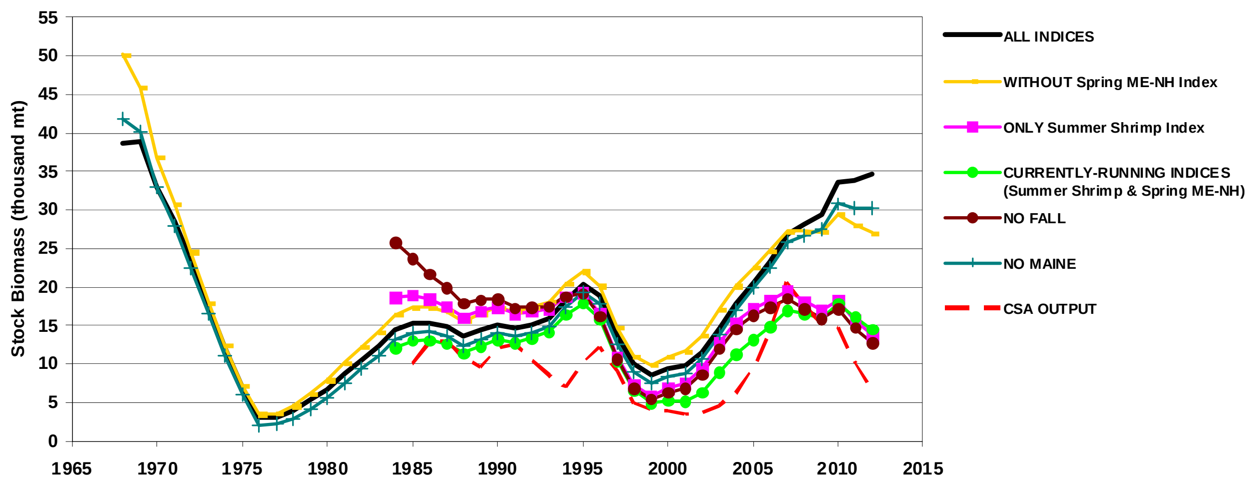


Figure 15. **Estimates of fishing mortality (above) and exploitable stock biomass (below) for northern shrimp from Catch-Survey analysis (CSA, red dashed line) and surplus production (ASPIC, solid lines) modeling. See Table 11 for more details about each run. The solid black line with no symbols represents the ASPIC output with all survey indices as input (Run 1).**

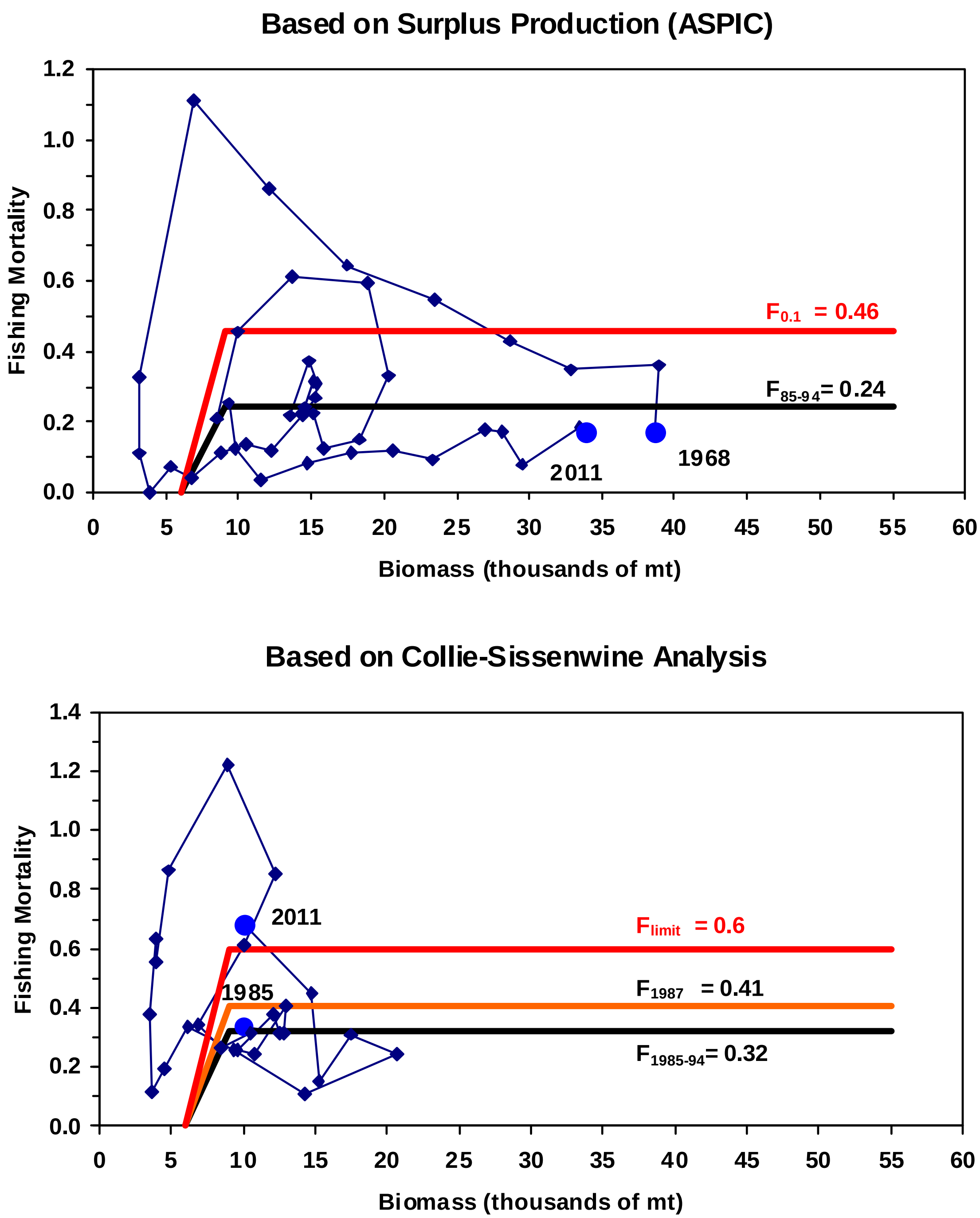


Figure 16. **Biomass dynamics of the Gulf of Maine northern shrimp fishery, from surplus production (ASPIC, Run 1) (above) and Collie-Sissenwine (CSA with M=0.25) (below) analyses, with fishing mortality and biomass reference points.**

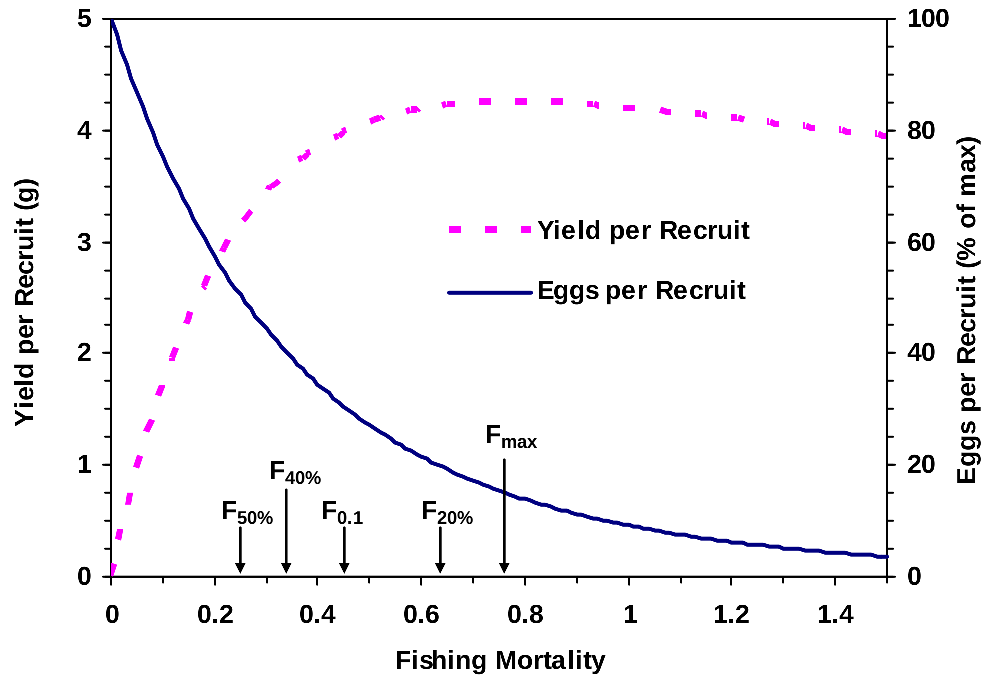


Figure 17. Yield and egg production per recruit for Gulf of Maine northern shrimp.

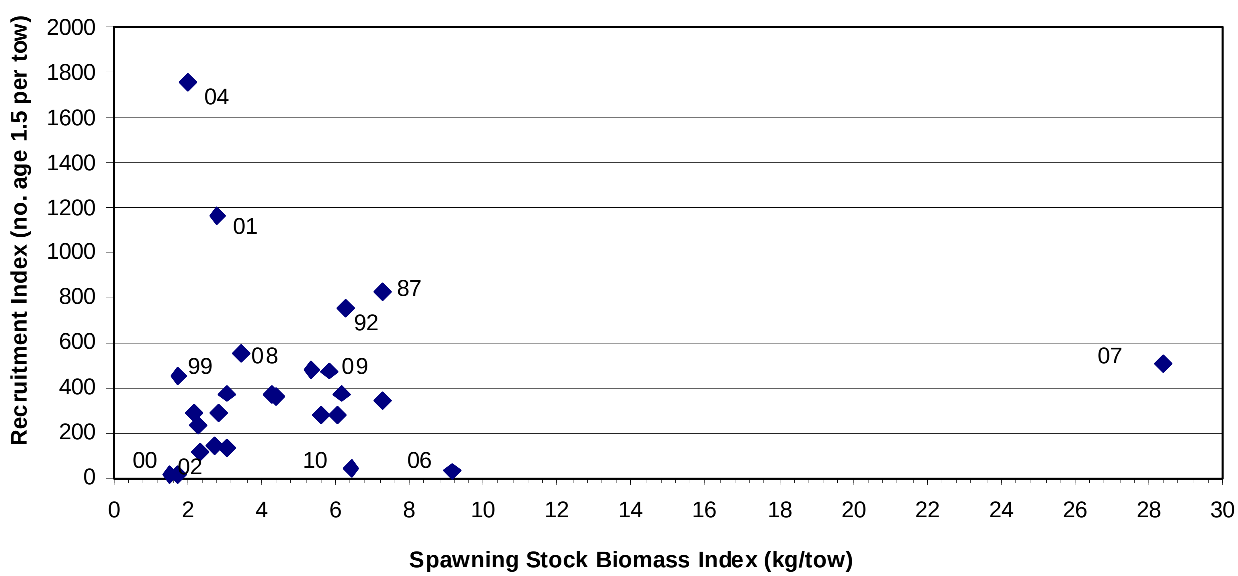


Figure 18. Relationship between summer survey index of Gulf of Maine female northern shrimp biomass the summer before spawning to age 1.5 abundance two years later. Two-digit numbers indicate the assumed age 1.5 year class.

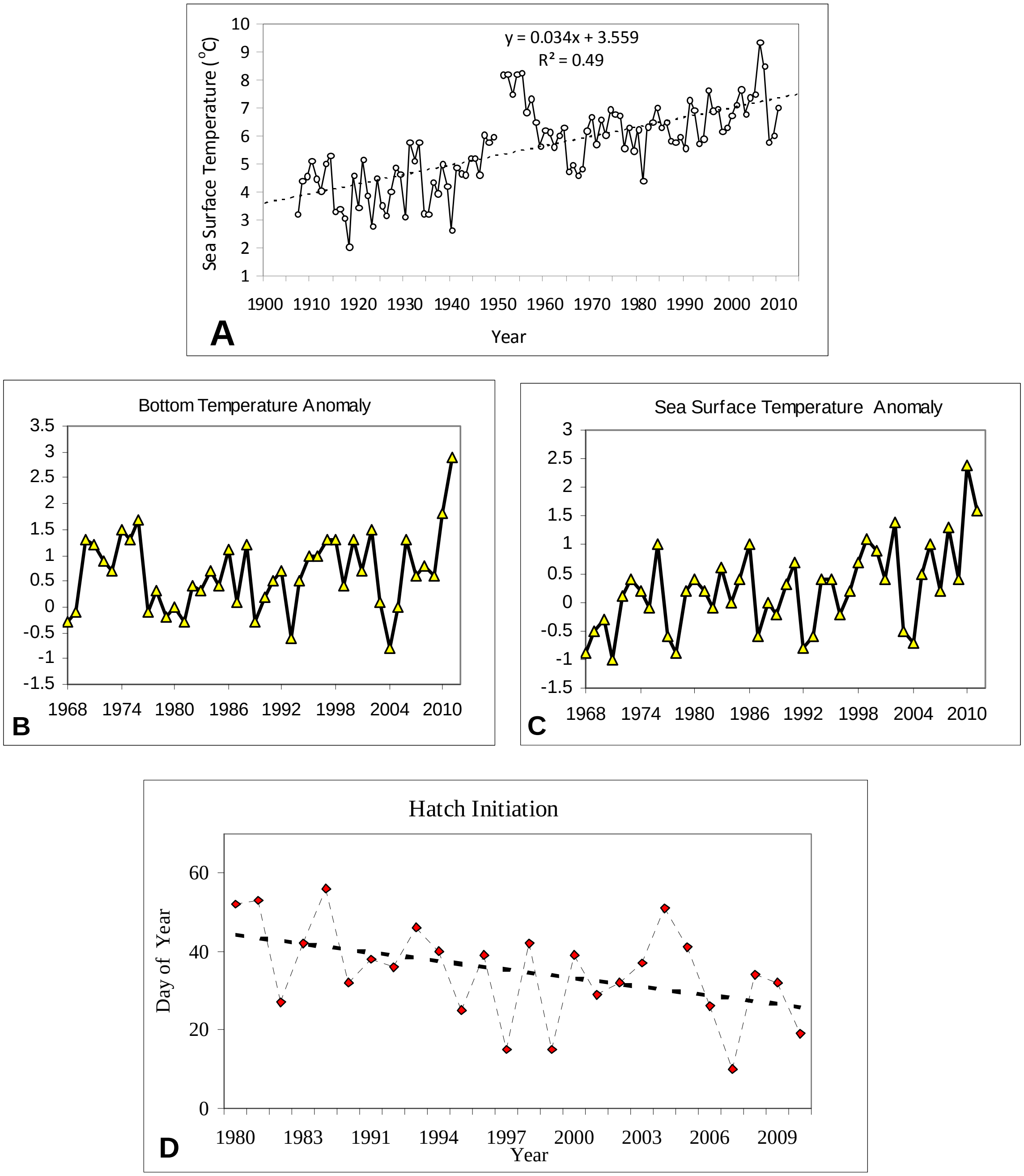
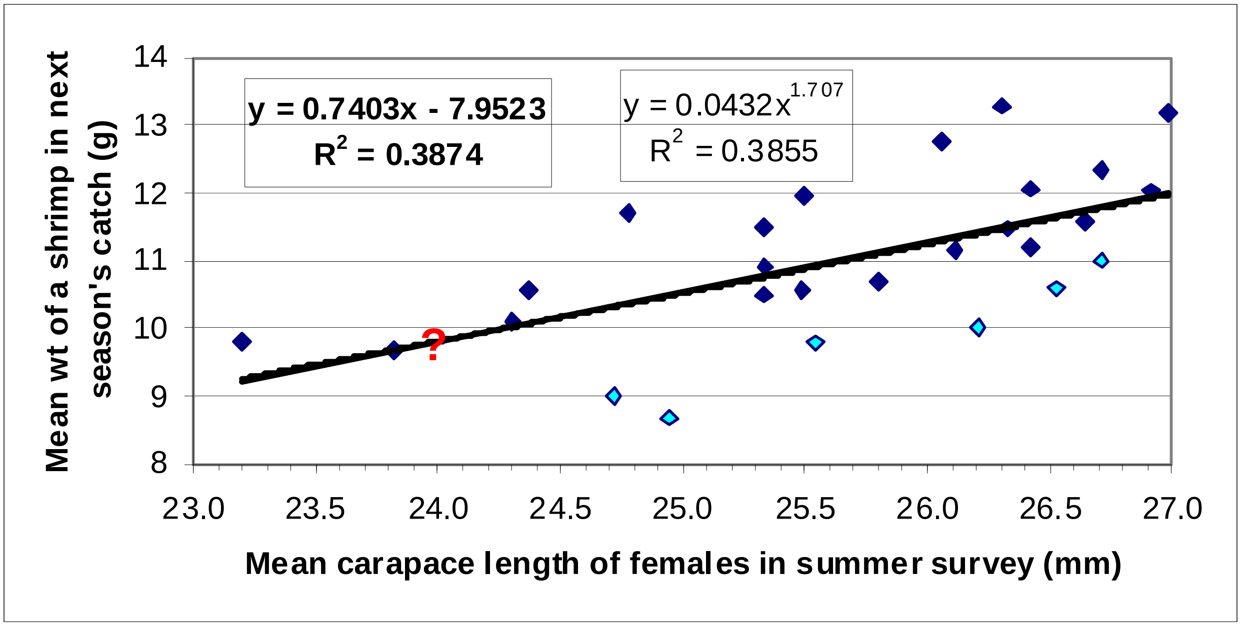


Figure 19. (A) Sea surface temperature during October-February measured at Boothbay Harbor, Maine, 1907-2010.
(B) Spring bottom temperature anomaly in the western Gulf of Maine measured during NEFSC trawl surveys, 1968-2011.
(C) Spring surface temperature anomaly in the western Gulf of Maine measured during NEFSC trawl surveys, 1968-2011.
(D) Estimated start date (day of year) of northern shrimp hatch period, 1980-1983 and 1989-2010 (no data for 1984-1988).



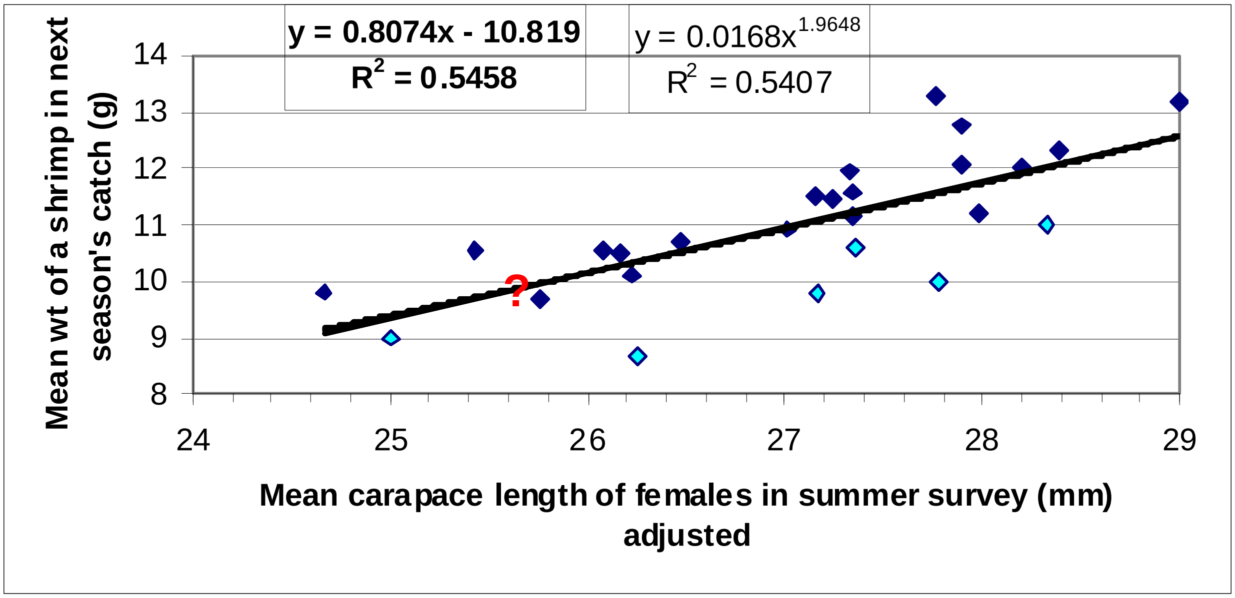


Figure 20. **Relationship between the mean weight of a shrimp in the commercial catch and the mean length of female shrimp in the previous summer survey (above), and the mean length of female shrimp adjusted upward by the proportion of females in the survey and downward by the abundance of assumed 2.5 year-old males (below). "?" indicates survey index during 2011, and predicted size in 2012 fishery.**

Appendix A

NATURAL MORTALITY

As mentioned above, natural mortality (M) was assumed to be 0.25, as approximated from the intercept of a regression of total mortality on effort (Rinaldo 1973, Shumway et al. 1985), as well as an estimate of Z for age-2+ shrimp from visual inspection of length modes from the Maine summer survey which was 0.17 from 1977 to 1978, when the fishery was closed (Clark 1981, 1982). These values, however, suggest, for the US GOM population as a whole, that M is low relative to estimates for other *Pandalus* stocks, which range from 0.2 to 1.0 (ICES 1977, Abramson 1980, Frechette and Labonte 1980, Shumway et al. 1985). Additionally, the value seems too low for a short-lived species.

The most recent SARC (NEFSC 2007) recommended further investigations into the possibility of higher values for M to be used to describe the status of the US northern shrimp resource. To date, the only work has been to view the implications as expressed in terms of CSA analyses. The SARC report includes preliminary work done to compare CSA estimates of biomass to estimates of biomass consumed by predators. These preliminary analyses indicate that CSA estimates of biomass are substantially less than the estimated biomass consumed by predators.

The current assessment model (CSA) was run under the assumptions of several levels of M (0.25, 0.40 and 0.60). The results are presented in Figure A1. When M is increased, the fishing mortality decreases. For this to occur, abundance and biomass increase as well. This process suggests better agreement between the CSA results and those of the predation studies. One problem, however, is that as M increases, F decreases to very small values. While this may be real, it becomes difficult for the current models to be able to fit these conditions. As a result, model fit, as described by confidence intervals and CV's indicates an increase in the analytical uncertainty. However, the response of the resource biomass to the resultant estimated fishing mortality for various levels of M indicated little change in terms of the current reference points.

It would be beneficial to continue investigations regarding this component of northern shrimp stock status.

ADDITIONAL REFERENCES

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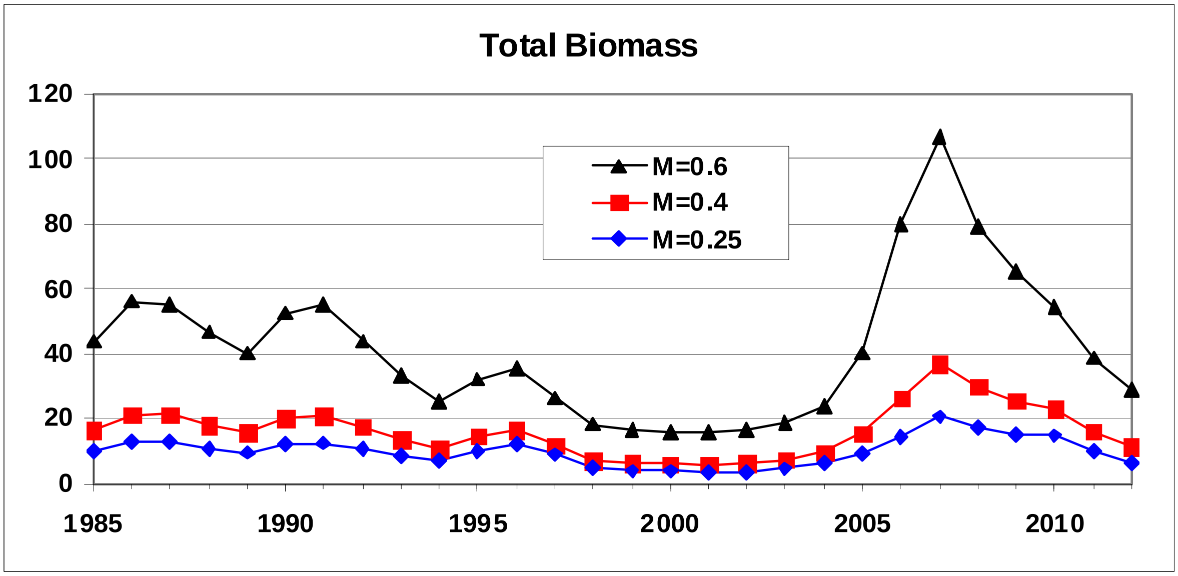

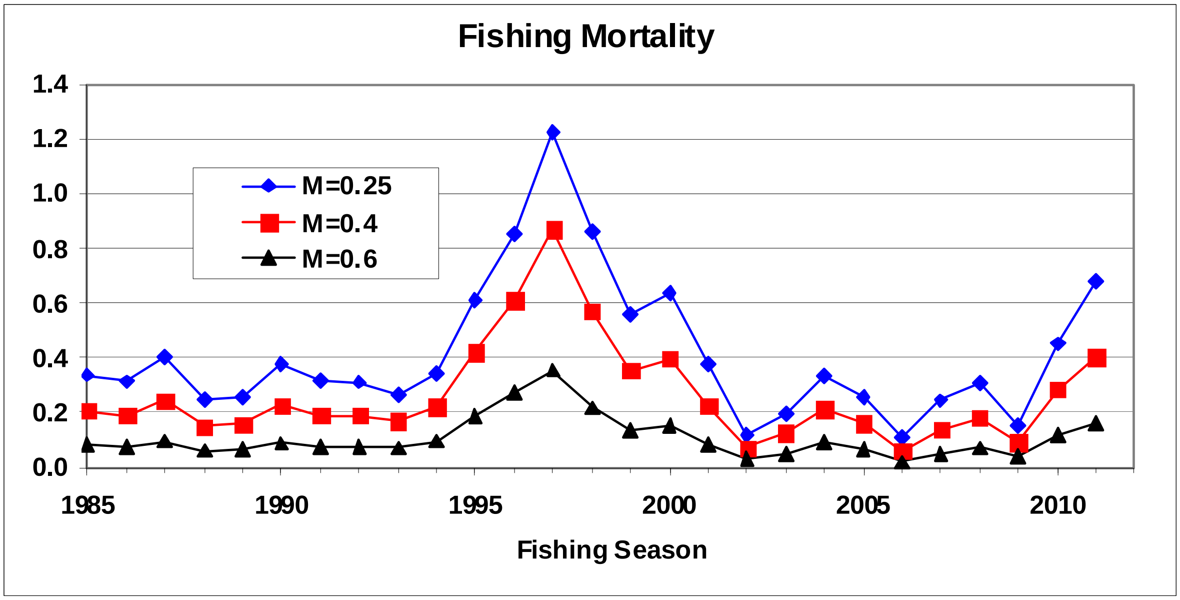

Figure A1. Biomass (above) and fishing mortality (below) of Gulf of Maine northern shrimp as estimated by CSA, assuming a natural mortality rate (M) of 0.25, 0.40, and 0.60.