Assessment Report for Gulf of Maine Northern Shrimp – 2013

ASMFC Northern Shrimp Technical Committee 2013

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ASSESSMENT REPORT

FOR

GULF OF MAINE NORTHERN SHRIMP – 2013

Prepared
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by the
Atlantic States Marine Fisheries Commission's
Northern Shrimp Technical Committee

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EXECUTIVE SUMMARY

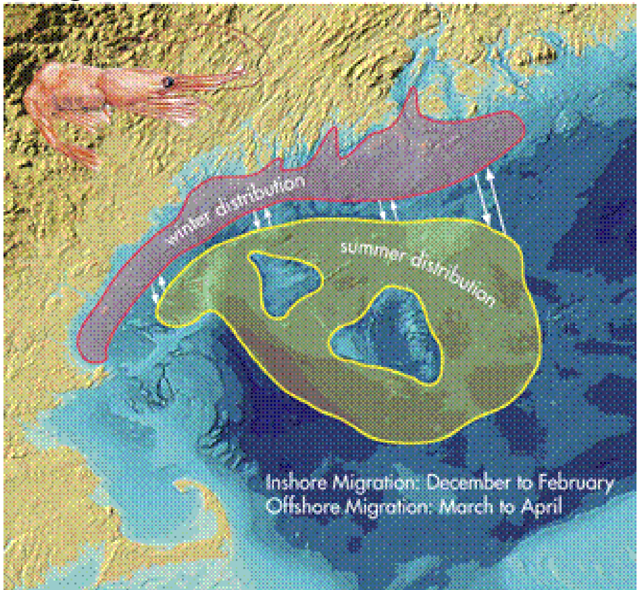
The Gulf of Maine fishery for northern shrimp is managed through an interstate agreement between the states of Maine, New Hampshire and Massachusetts. For the 2013 northern shrimp fishing season, the Northern Shrimp Section set a total allowable catch (TAC) of 625 metric tons (mt), subdivided into a research set aside of 5.44 mt, a trawl fishery TAC of 539.02 mt and a trap fishery TAC of 80.54 mt. Trawlers fished for 54 days and trappers fished 62 days culminating in 307.1 mt landed (preliminary), which was 312.46 mt (50%) under the 2013 fishery TAC. The average price per pound was $1.81, the highest observed in recorded history, and resulted in a preliminary estimated ex-vessel value of $1,223,045.

The Northern Shrimp Technical Committee provides recommendations to the Northern Shrimp Section based 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. In recent years, severe declines have been observed in all survey indices, including record low exploitable biomass and recruitment in 2012 and 2013. Environmental conditions have been unfavorable for recruitment of northern shrimp in recent years. Stock status, as inferred from assessment model estimates indicate that the stock is overfished and that overfishing occurred in 2012 and 2013. This was despite a 72% reduction in quota and the institution of other conservative measures in 2013 such as a late opening of the season to allow for 50% of hatch to occur. Despite the low catch targets in 2013, the TAC was not fully harvested and F_{target} and $F_{threshold}$ reference points were both exceeded.

Model results for 2012 and 2013 indicate that this stock has collapsed. Ancillary information (survey indices, fishery indicators) support this conclusion. Three successive years of recruitment failure and continuing warm temperatures indicate poor prospects for the near future, both in terms of the fishery and for stock recovery. Given these results, the NSTC recommends that the Section implement a moratorium on fishing in 2014 to maximize spawning potential of the population.

INTRODUCTION

Biological Characteristics



Distribution of adult female northern shrimp (NAMA, 2006)

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. 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 somewhat 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.

Fishery Management

The Gulf of Maine fishery for northern shrimp is managed through an interstate agreement between the states of Maine, New Hampshire and Massachusetts (the Northern Shrimp Section). 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, which was implemented in 2004, established biological reference points for the first time in the shrimp fishery and expanded the tools available to manage the fishery. Management of northern shrimp under Amendment 1 resulted in a rebuilt stock and increased fishing opportunities. However, early season closures occurred in the 2010 and 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).

In response to these issues, Amendment 2, approved 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. It 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. The fishing mortality target is defined as the average fishing mortality rate during 1985 to 1994 when biomass and landings were "stable" (F_{target}). The fishing mortality threshold is the maximum annual F during the same stable period ($F_{threshold}$). F_{target} and $F_{threshold}$ are re-estimated by the NSTC in each annual stock assessment update. The fishing mortality limit is F = 0.6, and is based on the value that was exceeded in the early to mid-1970s and in the mid-1990s when the stock collapsed. Overfishing is occurring if the threshold is exceeded.

Amendment 2 does not employ a biomass target because the Section did not want to set unlikely goals for a species whose biomass can easily be affected by environmental conditions. The stock biomass threshold of $B_{Threshold}$ = 9,000 metric tons (mt) and limit of B_{Limit} = 6,000 mt are based on historical abundance estimates and response to fishing pressure, and remain unchanged from Amendment 1. The limit was set at 2,000 mt higher than the lowest observed biomass. The Section stresses that the threshold is not a substitute for a target. It will manage the fishery to maintain stock biomass above the threshold. Furthermore, the Section's management decisions will be affected by the year class composition of the stock.

Addendum I to Amendment 2, approved in November 2012, clarifies the annual specification process, and allocates the TAC with 87% for the trawl fishery and 13% for the trap fishery based on historical landings by each gear type.

Management in the 2013 Season

The 2013 fishing season had a total allowable catch (TAC) of 625 metric tons (mt), subdivided into a research set aside of 5.44 mt, a trawl fishery TAC of 539.02 mt and a trap fishery TAC of 80.54 mt. The fisheries were to close when projected landings reached 85% of the fishery's TAC. The trawl season started January 23, 2013 with two landing days a week (Monday and Wednesday) and no trip limit. The trap season started February 5, 2013 with six landings days (every day but Sunday) and an 800 pound landing limit per vessel per day. In addition, the Section 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 increased the number of landings days for the trawl fishery from two to four (Monday, Tuesday, Thursday and Friday) on February 11, 2013. This was due to low landings since the start of the season and the desire to provide the trawl fishery with greater access to the resource.

The Section further increased the landing days (to seven days a week) for both the trawl and trap fisheries on March 13, 2013. The Section also removed the daily trip limit for the trap fishery. Despite these changes, the TAC was not harvested prior to the fisheries closing date (April 12, 2013).

The Section considered several factors in setting the specifications for the 2013 fishery. These included (1) the northern shrimp stock was overfished and overfishing was occurring for the last three years; (2) all survey indices were exhibiting a downward trend (since 2007, biomass had steadily declined and was at its lowest level); (3) poor recruitment (the number of shrimp surviving to age 1.5) in 2011 - 2013. Northern shrimp recruitment is related to both spawning biomass and ocean temperatures, with higher spawning biomass and colder temperatures producing stronger recruitment. Ocean temperatures in the western Gulf of Maine shrimp habitat had been increasing in recent years and had reached or approached unprecedented highs in the past three years (NEFSC trawl survey data, 1968-2012). This suggested an increasingly inhospitable environment for northern shrimp and indicated the critical need for protecting spawning biomass.

Fishery Assessment

Stock assessments conducted since the 1980's have identified strong year classes (e.g., those hatched in 1982, 1987, 1992, 2001, 2004). Strong year classes generally support the shrimp fishery for about three years commencing about three years after hatching. In its 2012 assessment, the NSTC estimated the exploitable biomass of shrimp to be the lowest during the modeled time period (1984-2012), and recommended a moratorium on fishing during the 2013 season, a recommendation which was not implemented by the Section.

The following report presents the results of the Technical Committee's 2013 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) data from federal and Maine vessel trip reports (VTRs) filed by shrimp fishers since 2001; and 4) biological sampling of the commercial landings by personnel from the participating states and the NMFS. In addition to index methods of assessing the stock (e.g. fishery trends, indices of abundance), population models including Collie-Sissenwine Analysis, ASPIC surplus production, and yield and egg 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 2013 are F_{target} =0.38 and $F_{threshold}$= 0.48. F_{limit} remains = 0.60. The terminal year estimate of fishing mortality from the 2013 stock assessment is F_{2013}= 0.53, above the target and also slightly above the threshold, and therefore overfishing is occurring. The current biomass reference points as established by Amendment 2 are $B_{threshold}$ = 9,000 mt and B_{limit} = 6,000 mt. The model estimates terminal year biomass as 500 mt, indicating that the biomass is well below the threshold, resulting in an overfished condition. Amendment 2 states that if the stock biomass goes below the threshold, the Section is required to take action to recover the stock above the threshold.

The current reference points are estimated within the assessment model framework using an assumption that natural mortality (M) = 0.25, as specified in Amendment 2. The NSTC notes that under an assumption that M=0.6 and recalculating reference points using the same methods as specified in Amendment 2, the stock status would still be overfished, and the stock would be experiencing overfishing.

COMMERCIAL FISHERY TRENDS

The NSTC reviewed state and federal harvester reports (vessel trip reports (VTRs)) for the 2001 through 2012 fishing seasons and dealer reports for the 2013 season. Correspondingly, landings and effort data in Tables 1-6, as well as associated figures for those years were updated. Landings in 2013 (preliminary) were 307 mt (previously the low was in 2002 at 453 mt).

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 6,400 mt during 1988-1995, and then rose dramatically to 9,500 mt in 1996, the highest since 1973. Landings declined to an average of 2,000 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 thought to be market-limited. The proposed 180-day season for 2010 was cut short to 156 days with 6,140 mt landed, due to the industry exceeding the total allowable catch (TAC) for that year, and concerns about small shrimp.

As in 2010, the 2011 season was closed early due to landings in excess of the TAC. A total of 6,397 mt of shrimp were landed, exceeding the TAC of 4,000 mt by approximately 2,400 mt (Table 1 and Figure 1). The average price per pound was $0.75 and the estimated landed value of the catch was $10.6 million (Table 1). In 2012, the season was further restricted by having trawlers begin on January 2 with 3 landings days per week and trappers begin on February 1 with a 1,000 pound limit per vessel per day. The TAC was set at 2,100 mt and would close when the projected landings reached 95%. The season was closed on February 17 and trawlers had a 21-day season and trappers had a 17-day season. Preliminary landings for 2012 were 2,476 mt and the average price per pound was $0.95 with an estimated landing value of $5.2 million.
In 2013, the TAC was set at 625 mt with 5.44 mt set aside for research tows and closure when 85% of the TAC was reached in each fishery (trap and trawl). The trawl fishery was allocated a 539.02 mt TAC and the trap fishery was allocated an 80.54 mt TAC. Trawlers fished for 54 days and trappers fished 62 days culminating with 307.1 mt landed (preliminary), which is 312.46 mt (50%) under the TAC. The average price per pound was $1.81 and is the highest observed in the northern shrimp fishery with a preliminary estimated value of $1,223,045.

Maine landed 83% (255.5 mt) of the 2013 season total, New Hampshire followed with 10% (31.3 mt) and Massachusetts landed 7% (20.3 mt) of the season total (preliminary data, Table 1). The proportional distribution of landings among the states was similar to 2003-2012, 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 2013 (Table 2 and Figure 2a, preliminary data) remained generally similar to past years, except for no landings in December since the fishery did not begin until January 23. The month of February yielded the highest proportion of the catch (62%) followed by January (23%) and March (14%) and April (1%).

Most northern shrimp fishing in the Gulf of Maine is conducted using 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 2011 and 9% in 2012, and 6% in 2013 (Table 3). Trapping effort had been increasing in recent years, accounting for 22% of Maine's landings in 2010, but may have been lower relative to trawling in 2011 (17%) and 2012 (9%) because of the early closure of the seasons.

Size, Sex, and Maturity Stage Composition of Landings

Size and sex-stage composition data were collected from port samples from each of the three states. One kilogram samples were collected from randomly selected catches. Data were expanded from the sample to the catch, and then from all sampled catches to landings for each gear type, state, and month. 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 to the fishery 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. Landings in 2008 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 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). Trawl catches in the 2012 fishery were likely 4-year-olds from the moderate 2008 year class, but they were small for their age. Low percentages of males and juveniles were caught in 2012 likely due to the later start date of January 2. In the 2013 fishery, catches were limited but likely comprised 4- and 5-year-olds from the moderate 2009 and 2008 year classes, but the shrimp were small for their assumed age. Limited numbers of males and transitionals were observed in 2013 catches. Massachusetts and New Hampshire had some in samples from January through March, and Maine observed some in April (Figures 3-4).

Maine trappers generally were more apt to catch females after egg hatch, than trawlers, as in previous years (Figure 3b). See the table below for the average counts per pound by month and gear. Average counts per pound were lower in Maine than in Massachusetts and New Hampshire in January, February, and March.

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

2013 Mean Counts per Pound, all shrimp species	Jan	Feb	Mar	Apr
Maine Trawls	42	43	45	47
Maine Traps	-	43	41	n/a
All Maine	42	43	45	47
Massachusetts	52	51	54	n/a
New Hampshire	47	50	51	n/a

n/a = no samples

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).

Pre-season research tows were conducted to obtain information on catch rates and egg hatch. Three shrimp trawlers from Maine (from South Bristol, Stonington, and Sebasco) and one from New Hampshire conducted experimental tows for one day during the week of January 13, 2013. They were required to carry an observer, make short (half-hour) tows in several areas, and were not to exceed 1,500 lbs per boat for the day. They provided samples of the shrimp from each tow for analysis by ME DMR and NH F&G. The boats were not paid, but were allowed to sell their catch. Catch rates were much lower than the 1991-2013 Maine commercial trawl fishery average of 250 lbs/hr (Table 7). Counts per pound varied greatly, generally from east to west, with 34 for the Stonington boat, 38 for the South Bristol boat, 51 for the Sebasco boat, and 48 for the Portsmouth boat. Egg hatch also varied from east to west, with almost no hatch in Stonington, to 26% hatched off near Sebasco, to 88% hatched off near Portsmouth, NH (Figure 3a).

Trappers also set pre-season traps. Five shrimp trappers from midcoast Maine (from Boothbay to Vinalhaven) set experimental pre-season shrimp traps between January 24 and February 2, 2013. Each trapper was allowed to set and haul up to 6 traps. Catch rates were poor, less than 1 pound per trap. One sample was collected from the Boothbay Harbor area, with 16% of shrimp carrying eggs and 84% hatched off (Figure 3a).

For more information about the pre-season trawling and trapping, visit http://www.maine.gov/dmr/rm/shrimp/.

According to port samples from the 2013 season catches, in January, in Maine, 22.5% of the trawled catch was female stage II; in February this increased to 45%. These percentages are higher in 2010 through 2013 than in past seasons, suggesting that egg hatch is occurring somewhat earlier than in 2008 and 2009 (2008: 5.4% in January, 13.5% in February and 2009: 5.8% in January, 17.8% in February). However, the estimate of percent hatched in January in 2013 may be biased because of the late start of the season (samples came from late January rather than from the whole month).

In New Hampshire trawl catches, the percentage of female stage II shrimp for the 2013 season was 95.6% in January, and 88% in February. In Massachusetts trawl catch samples, the percentage of female stage II shrimp was 75.6% in January, and 81.2% in February. Egg hatch was well underway when compared to 2012 (NH: 60.2% in January, 94.6% in February, MA: 17.9% in January, 49.2% in February) (Figure 4). New Hampshire and Massachusetts percentages of stage II shrimp in the catch were higher than Maine for the same months, probably reflecting the eastern Gulf lagging the west in the timing of egg hatch.

Discards

Discard rates of northern shrimp in the northern shrimp fishery are thought to be near zero because no size limits are in effect and most fishing effort occurs in areas where only the larger females are present. Data from a study which sampled the northern shrimp trap fishery indicated overall discard/kept ratios (kg) for northern shrimp of 0.2% in 2010 and 0.1% in 2011 (Moffett et al. 2012). Sea sampling data from Gulf of Maine shrimp trawlers in the 1990s indicated no discarding of northern shrimp (Richards and Hendrickson 2006). On an anecdotal level, port samplers in Maine reported seeing manual shakers (used to separate the small shrimp) on a few trawl vessels during April 2010, but made no similar observations in 2011 through 2013. Discarding of northern shrimp in other Gulf of Maine fisheries is rare (on average less than 0.001% during 2000-2012; Northeast Fishery Observer Program data, NMFS). For these reasons and because detailed data for estimating potential discards are lacking, shrimp discards from the shrimp and other fisheries are assumed zero 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 2004-2013 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 1970s, effort in the fishery (measured by numbers of trips in which shrimp gear is used) has increased and then decreased on several occasions (Tables 4 and 5, Figure 6). In the 1980s there was a gradual increase in the total number of trips to a peak of 12,497 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 1,304 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 3,866 trips in 2005. Trips in 2006 dropped to 2,478, likely due to poor market conditions, increased in 2007 to 4,163, and increased in 2008 to 5,587, the most trips since 1999.

In 2009, the length of the season was increased to 180 days while the effort decreased to 3,002 trips, likely caused by limited demand from the processors and poor market conditions. In what turned out to be a 156-day season in 2010, effort increased dramatically to 5,979 trips. 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 a higher effort than 2010 with 7,095 trips. The high level of effort was again due in part to a limited supply in Canada and demand from local markets. In 2012, the number of trips decreased to 3,648 due to the shortened season. The effort further decreased in 2013 to 1,322 trips, likely due to a low quota and poor fishing conditions (Table 4) (preliminary data).

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. In 2013, there were 198 vessels; 122 from Maine, 16 from Massachusetts, and 14 from New Hampshire, according to dealer logbook data (preliminary). Of the 122 vessels from Maine, 46 were trapping (Table 6).

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 2012 and 2013 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. There were 92 interviews with Maine trawler captains in 2013; 26 were in January, 49 were in February, 14 were in March, and 3 were in April. Of those interviewed in January, 81% were fishing inshore, increasing to 90% in February, then 64% in March, and none of the 3 interviewed in April were fishing inshore. Overall, 80% of those interviewed fished inshore and 20% fished offshore.

Locations of 2013 fishing trips and landings from federal and state VTRs (still incomplete at this time) 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 (1995-2012), and Maine port interview data (1991-2013) and are measures of resource abundance and availability (Table 7 and Figure 6). 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 trawl and trap trips, and 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, and in 2012 and 2013, Maine DMR imposed day-length limits.

Pounds landed per trip (lbs/trip), from VTRs, averaged 1,410 pounds during 1995-2000. In 2001, the catch per trip dropped to 752 pounds, the lowest since 1994, and remained low, at 765 pounds, in 2002. During 2003 – 2005 it averaged 1,407 lbs/trip. The increasing trend continued in 2006 with 2,066 pounds per trip. In 2007, the highest pounds per trip of the time series was observed with 2,584 pounds. During 2008-2011, pounds per trip averaged 2,012, with a value of 2,264 in 2010, which is the second highest in the time series. There was a large decrease in 2012 to 1,497 lbs/trip (preliminary). In 2013, the average pounds landed per trip was 512, with 579 lbs per trawl trip, both the lowest of their time series (preliminary, Table 7 and Figure 6).

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 6). Maine’s inshore trawl CPUE for 2013 was 118 lbs/hr, offshore was 78 lbs/hr, and the season average was 110 lbs/hr, less than half the time series average of 249 lbs/hr (Table 7).

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 shrimp trawl 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 are also considered (see survey locations in Figure 8a.).

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the state-federal summer survey from 1984-2013 are given in Table 9 and Figures 8c and 11, and length-frequencies by year are provided in Figure 12. The 2013 indices were the lowest on record, with a log*e* transformed mean weight per tow of 1.0 kg/tow. The series 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 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 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 8.6 kg/tow in 2011, 2.5 kg/tow in 2012, and 1.0 kg/tow in 2013. These most recent values are well below the time series average of 12.9 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 367 individuals per tow. From 2008 to 2010, the age 1.5 index varied around 500 individuals per tow (506, 555, 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 44 individuals per tow in 2011, signifying a weak 2010 year class. The 2012 index for age 1.5 was the worst in the time series (until 2013), with only 7 individuals per tow, signifying an extremely weak 2011 year class. The 2013 age 1.5 index dropped even further with only 1 individual per tow, signifying a very weak 2012 year class and an unprecedented three consecutive years of poor recruitment.

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 12), 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 6.0 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. Since 2009, the index has been below the time-series mean and has declined steadily to new time-series lows of 0.9 kg/tow in 2012 and 0.3 kg/tow in 2013 (Table 9 and Figures 11-12). The low values in 2012 and 2013 are most likely due to weak recruitment of the 2010 and 2011 year classes, poor survival of the moderate 2008 and 2009 year classes, and overall small size (carapace length) of female shrimp from those year classes.

The NEFSC autumn survey, conducted by the FRV *Albatross IV*, provided an index of shrimp abundance from 1968 to 2008 (Table 13, 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. In 2009, the NEFSC fall survey changed vessels and protocols, thus indices since 2009 are not directly comparable to earlier years. However, the biomass index from the new NEFSC fall survey has declined rapidly since 2009 (Figure 9), parallel to recent trends in the summer shrimp survey and the ME-NH survey.

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), beginning in 2000. A deeper stratum (4 = > 55 fa out to about 12 miles) 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 13. 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 17.86 kg/tow in spring 2011. However, the index dropped abruptly in 2012 when the index declined to 7.50 kg/tow and then dropped further in 2013 to only 1.69 kg/tow. The 2013 index is well below the time-series average of 9.60 kg/tow.

The low index values in the state-federal summer survey in the most recent years have raised concerns that the survey is no longer adequately tracking abundance. The NSTC examined some of the potential hypotheses to explain the changes. One hypothesis that has been put forward is that the bulk of the northern shrimp population has moved north, outside of the area covered by the summer survey. The NEFSC bottom trawl survey samples the entire Gulf of Maine, and although 2013 fall survey data are not yet available, the 2009 – 2012 survey data do not suggest a significant shift in distribution of shrimp that would explain the recent decline in abundance indices in the summer survey. Patchiness in the distribution of shrimp in the summer survey appears has increased steadily since 2008, but does not appear to be strongly related to temperature; however, there was some evidence in 2013 of higher densitities of shrimp at cooler temperature stations. Indices based on randomly selected stations show the same trends in abundance as indices based on fixed stations. Three additional fixed stations were added to the 2013 summer survey in Stratum 10 (Figure 8a), based on harvester recommended sites. These stations caught an average of 3.7 kg/tow (32 lbs/hr, untransformed, Figure 8d). This does not provide support for the idea that the shrimp have moved north or eastward.

From 2007 to 2011, the ME-NH inshore trawl survey data did not match the declining trend in the summer survey data. Trends in the spring ME/NH survey may be affected by inter-annual variation in the timing of the offshore migration of post-hatch females. However, the low 2012 and 2013 index values in the ME-NH survey are consistent with the 2012 and 2013 summer survey results in showing a severe drop in abundance. This survey also has not provided any evidence of a shift in shrimp populations to the north or east (Figure 8b).

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. 2012). During the warm period of the 1950s, northern shrimp catches declined to zero despite continued fishing effort (Dow 1964), suggesting a population collapse. Spring ocean temperatures during the larval period are particularly important for recruitment, with cooler temperatures favoring higher recruitment (Richards et al. 2012). Spawner abundance also influences recruitment strength, with more recruits resulting from higher spawner abundance (Richards et al. 2012 and Figure 19). Timing of the larval hatch is influenced by temperature during late spring through early winter (Richards 2012).

Sea surface temperature (SST) has been measured since 1905 at Boothbay Harbor, Maine, near the center of the inshore nursery areas for northern shrimp. Annual average SST at Boothbay has increased (Figure 20a) from an average of 7.9º C during 1906-1948 to an average of 10.4º C during 2000-2012. SST has exceeded the 1953 high point three times in the past decade, and 2012 was the warmest year in the 108 years of record. Similar trends have been seen during March-April, a critical time for determining recruitment strength (Figure 20b). During 2013, the March-April average SST (5.0º C) was cooler than in 2012 (6.9º C), but still well above the 20th century average (3.4º C) (Figure 20b).

Spring temperature anomalies (deviations measured relative to a standard time period) in offshore shrimp habitat areas were the highest on record during 2012 (surface temperature) and 2011-2012 (bottom temperature) (NEFSC trawl survey data, 1968-2012; Figures 20c and 20d). Spring surface temperature in 2013 was only slightly below the record 2012 anomaly, while bottom temperatures declined but were still relatively high. The start of the hatch period has become earlier as temperatures have increased, with the hatch now beginning more than a month earlier than before 2000 (10% line in Figure 20e). The midpoint of the hatch period has changed less than the hatch start, but has trended earlier since 2008 (50% line in Figure 20e).

ANALYTICAL STOCK ASSESSMENT

Descriptive information for the Gulf of Maine shrimp fishery (total catch, port samples, trawl selectivity, survey catches, and life history) was 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 shrimp entering the fishery each year using total catches and summer survey indices (Table 10). 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 (Table 13). A yield-per-recruit and eggs-per-recruit model (Cadrin et al. 1999) simulates the life history of shrimp (including growth rates, sex 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.

Catch-Survey Analysis (CSA)

The CSA model was run under two assumptions regarding natural mortality (M) (M=0.25 and M=0.6). The assumption of M=0.25 is based on direct estimates from northern shrimp population and fishery data, approximated from a regression of total mortality on effort (Rinaldo 1973, Shumway et al. 1985), and from catch curve analysis of survey data for age 2+ shrimp during a fishery closure (1977-1978, M=0.17) (Clark 1981, 1982). However, the value of M=0.25 is low relative to that assumed for other *Pandalus* stocks, which range from 0.2 to 1.0 (ICES 1977, Abramson 1980, Frechette and Labonte 1980, Shumway et al. 1985), and is low given the short life span of the species. The most recent peer review of the shrimp assessment (NE Regional SARC 2007) recommended further investigation of appropriate values of M and suggested that a value of M=0.6 is likely more realistic than M=0.25.

CSA-based estimates are summarized in Tables 11a (M=0.25) and 11b (M=0.6) and Figures 13-14. Model diagnostics are given in Table 12 and discussed below. The effect of changing the assumption of M was primarily to scale the estimates, with higher biomass and abundance and lower F estimated under M=0.6 than under M=0.25. However, trends in population size and fishing mortality were similar regardless of the assumed M (Figure 13-14).

The CSA model estimates showed that exploitable biomass and abundance varied about a constant level during the mid-1980s to mid-1990s, then declined to low levels until around 2004, when they began to increase, reaching the time series high in 2007. Since then abundance and biomass declined steadily to the lowest value on record in 2012, and then declined even further in 2013. Fishing mortality (F) varied without trend during 1985-1994, increased rapidly to a peak in 1997, then declined, fluctuating without trend during 2002-2009. Fishing mortality increased to the time series high in 2012, but dropped in 2013 (terminal year estimate not adjusted for retrospective).

Model diagnostics were explored to compare the models (Table 12). The relative bias and precision of the model estimates of abundance and F were estimated by bootstrapping, in which survey measurement errors were randomly re-sampled with replacement 1000 times to provide simulated replications of the model. The percent bias in the abundance estimates was very low with slight underestimation for both models. The percent bias of F estimates was larger than the bias in abundance, and was greater in the M=0.6 model (21%) than in the M=0.25 model (15%). Precision of model estimates as indicated by the average coefficient of variation (CV) was somewhat better for the M=0.25 model than for the M=0.6 model, but neither model was highly precise. A measure of overall model fit (Akiake's Information Criterion, AIC) which compares model estimates of relative abundance with observed relative abundance indices (Figure 13a) indicated that the M=0.6 estimates of relative abundance were closer to the observed survey indices than those from the M=0.25 model. Mohn's rho (Mohn 1999) was used to evaluate retrospective patterns in both models. Retrospective patterns provide an indication of the stability of the model, and help with interpretation of terminal year estimates, which are typically the most uncertain. Mohn's rho characterizes the relative difference between estimates for a given year from a full time series model to estimates for that year if the model ended in that year. The data for the statistic are generated by sequentially removing a year from the end of the time series and re-estimating the model. We sequentially removed 4 years from the time series to estimate Mohn's rho in recent years. Retrospective patterns for both models have become quite pronounced, with terminal year total abundance overestimated by 123% (M=0.25) and 364% (M=0.6). Terminal year F was underestimated by both models (45% for M=0.25, 73% for M=0.60). These retrospective patterns likely stem from the extreme 2006 survey observations, followed by the severe drop in recruitment in 2011 and in all life stages in 2012. Prior to 2006, the retrospective patterns in the model were minimal (NE Regional SARC 2007).

In summary, trends modeled by CSA are similar regardless of the assumption of M, and both models currently have diagnostic issues, most importantly large retrospective patterns indicating that terminal year abundance is overestimated and F is underestimated. The retrospective problems are more severe in the M=0.6 model. Both models show a continued decline in abundance and biomass of exploitable northern shrimp to time series lows, high fishing mortality in 2011 and 2012, and lower but still relatively high mortality in 2013.

Surplus Production Model (ASPIC)

An alternative method of estimating stock size and F was compared to results from the CSA analysis. A surplus production model (ASPIC, Prager 2004) was fit to seasonal catch and survey biomass indices from 1968 to 2013 (summarized in Table 13; Figure 16a). Surplus production models such as ASPIC are generally used to track relative trends in biomass and F rather than to derive absolute estimates of these quantities. This is particularly true for species with highly variable recruitment such as northern shrimp, because the model is not able to track the rapid changes in abundance resulting from recruitment pulses (Figure 16a). Estimates of F and biomass from the surplus production model confirmed broad trends estimated by the CSA model (Figures 16b and 16d). In both the CSA and ASPIC models, biomass estimates have been rapidly declining since 2007 (Table 13, Figure 16).

Estimates of biomass from the base model run of ASPIC, which includes all four available fishery independent indices, were below B_{MSY} in 2013 indicating the stock is overfished (Table 13). This is consistent with the CSA model results. Estimates of F from the production model were below F_{MSY} in 2013, but above it in 2011 and 2012, indicating the stock has experienced overfishing for two of the last three years (Table 13). Retrospective analyses of results indicate that stock size has been considerably overestimated and the fishing mortality rate has been underestimated by the ASPIC model in recent years (Figure 16c). Agreement between CSA and ASPIC model results improved markedly in 2013, likely due to the consistent downward trend observed across multiple survey indices since 2011 (Figures 16a and d, Figure 17).

The CSA model is preferred over the surplus production model for assessing stock status because the CSA model uses empirical observations of recruitment to inform its estimates of population trends, while the surplus production model estimates a single intrinsic growth rate for the population over the whole time-series. As a result, CSA is more accurate in following trends in population size that are driven by northern shrimp's variable recruitment rates (Figure 13a). The surplus production model tends to smooth these trends out over the entire time-series and thus overestimates population size in years with weak year classes and underestimates in years influenced by strong year classes (Figure 16a). With both the CSA and surplus production models, terminal year values of fishing mortality and biomass are typically poorly estimated (Figures 14b and 16c).

Per Recruit Models

Yield per recruit and percent maximum spawning potential were estimated for the Gulf of Maine northern shrimp fishery (Table 14, 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). The index of annual egg production, calculated from stratified mean number of females at length from the summer shrimp survey and estimated fecundity at length (Shumway et al. 1985), reached its lowest value in 2013 (Figure 18).

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, and because temperatures have risen sharply in recent years (see discussion under Environmental Conditions above), F20% may no longer provide sufficient protection to prevent collapse under current conditions. The currently defined target F (=0.38, average F from 1985 through 1994) allows 30-40% of maximum egg production per recruit (Table 14).

SUMMARY

Landings in the Gulf of Maine northern shrimp fishery since the mid-1980s have fluctuated between 307-9,500 mt, reflecting variations in year class strength as well as regulatory measures, participation, and market conditions in the fishery. A peak of 9,500 mt was reached in 1996, after which landings declined steadily to a low in 2002 (450 mt). After 2002, landings generally increased, reaching another peak of around 6,000 mt in 2010 and 2011. Preliminary landings (not accounting for late reporting) in 2013 declined to 307 mt, which was 49% of the TAC set by ASMFC for 2013 (625 mt).

The number of fishing vessels participating in the northern shrimp fishery dropped from a high in 1996 (347 vessels) to an average below 200 vessels during 2002-2007. In 2013, an estimated 198 vessels participated (152 trawl, 46 trap). Trap catches accounted for about 12% of Maine's landings during 2001 to 2007, 18% during 2008 to 2011, and 8% since then.

Fishing mortality rates (F) as calculated by CSA under M=0.25 and M=0.60 followed trends similar to the landings, with a peak in 1997 that was about 300% above F_{target} and a low in 2002 that was about 37% below F_{target}. F varied around a relatively low level during 2003-2009 (average 28% below F_{target}), after which F began to increase. F reached the highest value in the time series in 2012 (~200% above F_{limit}). In 2013, F dropped to 0.53 which is below F_{limit} but still above F_{target} and $F_{threshold}$. Terminal year estimates are the most poorly estimated, and in recent years terminal F has been underestimated. The FMP target F was re-estimated in this assessment as $F_{1985\text{-}94}$=0.38 (under M=0.25), and the FMP threshold F_{1987}=0.48 (under M=0.25) (Table 11a and Figure 15).

Trends in total exploitable stock biomass as estimated from CSA under M=0.25 and M=0.60 show a stable period during 1985-1997, a decline to lower biomass during 1998-2004, then increasing biomass to a time series high in 2007. Since 2007 biomass has steadily declined and reached its lowest level in 2013 of about 500 mt assuming M=0.25 (1,500 mt assuming M=0.6). Terminal year biomass estimates have been over-estimated in recent years, suggesting that the biomass estimate for 2013 may be optimistic. The estimated biomass in 2013 is 5.2% of the estimated biomass during the stable period. Results from ASPIC were similar, with the population size in 2014 estimated as 10% of B_{MSY}. By accepted definitions of stock collapse (10% of unfished biomass, Worm et al. 2009; 20% of B_{MSY}, Pinsky et al., 2011), this stock has collapsed.

Evaluation of stock status with respect to biological reference points defined in the ASMFC Northern Shrimp Fishery Management Plan and its Amendments indicates that the stock was overfished and that overfishing occurred during the 2010-2013 fishing seasons (Figure 15). Stock status evaluation for 2012 and 2013 was the same (overfished, overfishing occurring) regardless of the assumption of natural mortality (M=0.25 or M=0.6).

Periods of good landings have generally followed recruitment of strong year classes as indicated by the summer survey. In the 2013 fishery, the female population was composed of the 2008 and 2009 year classes (5- and 4-year-old females, respectively). Both of these year classes were above average in abundance when they first appeared in the 2009 and 2010 summer surveys. However, in the 2012 survey these age classes had declined to very low levels, and the size of individuals was relatively small. The 2013 survey found further reductions in the abundance of female shrimp. Of additional concern for this and future years are the low recruitment indices for the 2010 -2012 year classes (from the 2011 -2013 summer surveys), which would begin entering the fishery as females in 2014. Recruitment indices for the 2011 and 2012 year classes were the lowest on record. The recruitment failure of three consecutive year classes is unprecedented. Given the severe declines in abundance across survey indices, as well as the poor stock status from model estimates and other fishery indicators, the NSTC considers the Gulf of Maine northern shrimp stock to have collapsed with little prospect of recovery in the near future.

Recruitment of northern shrimp is related to both spawning biomass and ocean temperatures, with higher spawning biomass and colder temperatures producing stronger recruitment. Ocean temperatures in western Gulf of Maine shrimp habitat have been increasing in recent years and have reached or approached unprecedented highs in the past three years. This suggests an increasingly inhospitable environment for northern shrimp and indicates the critical need for protecting remaining spawning biomass.

RECOMMENDATIONS

The NSTC bases its recommendations to the Northern Shrimp 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).

Short-term commercial prospects for the 2014 fishing season are very poor given the low abundance of all stages of shrimp in the 2013 survey, the relatively small size of females in the 2011 - 2013 surveys, and the low level of exploitable biomass estimated by CSA. The summer survey index of shrimp of carapace length greater than 22 mm (0.3 kg/tow) was the lowest in the 1984-2013 survey time series (1984-2012 average = 6.0 kg/tow).

Longer-term prospects are also poor due to low abundance of age 1.5 shrimp seen in the 2011 - 2013 summer surveys, suggesting recruitment failure for the 2010-2012 year classes. The 2010 year class began to enter the fishery in 2013, and has influenced the very low exploitable biomass for 2014 estimated by CSA.

Current trends in environmental conditions are not favorable for northern shrimp and may be a factor in the poor recruitment of the 2010-2012 year-classes. This suggests a need to conserve spawners and/or to allow hatching to take place prior to the fishery to help compensate for what may continue to be an unfavorable environment.

Given the current condition of the resource (collapsed, overfished, and overfishing occurring) and poor prospects for the near future, the NSTC recommends that the Section implement a moratorium on fishing in 2014. The NSTC notes that even with the small quota for 2013, the quota was not fully harvested and F_{target} and $F_{threshold}$ were both exceeded.

If the Section decides to allow a fishery, projected landings under a range of F's were estimated as:

$$\text{Yield}_{2014} = F * (R_{2014} + N_{2014})\, e^{-p*M}\, w_{2014}$$

Where F = fishing mortality rate
R = CSA-estimated abundance of recruits at time of survey
N = CSA-estimated abundance of full-recruited shrimp at time of survey
p = proportion of year between mean survey date and start of fishery
M= natural mortality
w = projected mean size of shrimp in the 2014 fishery (=11.64 g), estimated from relationship between mean size in the summer survey and mean size in the subsequent year's fishery during 2000-2013 (Figure 21).

The resulting estimates were as follows:

F level	Estimated Catch (mt)	
	if M=0.25	if M=0.6
25% of F_{target}	41	50
50% of F_{target}	81	101
75% of F_{target}	122	151
F_{target}	163	201
$F_{threshold}$	205	246

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

Year	Maine		Massachusetts		New Hampshire		Total	
	Annual	Season	Annual	Season	Annual	Season	Annual	Season
1958	2.2		0.0		0.0		2.2	
1959	5.5		2.3		0.0		7.8	
1960	40.4		0.5		0.0		40.9	
1961	30.5		0.3		0.0		30.8	
1962	159.5		16.2		0.0		175.7	
1963	244.3		10.4		0.0		254.7	
1964	419.4		3.1		0.0		422.5	
1965	941.3		8.0		0.0		949.3	
1966	1,737.8		10.5		18.1		1,766.4	
1967	3,141.2		10.0		20.0		3,171.2	
1968	6,515.2		51.9		43.1		6,610.2	
1969	10,993.1		1,773.1		58.1		12,824.3	
1970	7,712.8		2,902.3		54.4		10,669.5	
1971	8,354.8		2,724.0		50.8		11,129.6	
1972	7,515.6		3,504.6		74.8		11,095.0	
1973	5,476.6		3,868.2		59.9		9,404.7	
1974	4,430.7		3,477.3		36.7		7,944.7	
1975	3,177.2		2,080.0		29.4		5,286.6	
1976	617.3		397.8		7.3		1,022.4	
1977	142.1		236.9		2.2		381.2	
1978	0.0		3.3		0.0		3.3	
1979	32.8		405.9		0.0		438.7	
1980	69.6		256.9		6.3		332.8	
1981	530.0		539.4		4.5		1,073.9	
1982	883.0		658.5		32.8		1,574.3	
1983	1,029.2		508.2		36.5		1,573.9	
1984	2,564.7		565.4		96.8		3,226.9	
1985	2,957.0	2,946.4	1,030.5	968.8	207.4	216.7	4,194.9	4,131.9
1986	3,407.2	3,268.2	1,085.7	1,136.3	191.1	230.5	4,684.0	4,635.0
1987	3,534.2	3,680.2	1,338.7	1,427.9	152.5	157.9	5,025.4	5,266.0
1988	2,272.5	2,258.4	632.7	619.6	173.1	157.6	3,078.3	3,035.6
1989	2,544.8	2,384.0	751.6	699.9	314.3	231.5	3,610.7	3,315.4

Table 1a continued – U.S. commercial landings of northern shrimp (*2012 and 2013 data are preliminary)

Year	Maine		Massachusetts		New Hampshire		Total	
	Annual	Season	Annual	Season	Annual	Season	Annual	Season
1990	2,962.1	3,236.3	993.4	974.9	447.3	451.3	4,402.8	4,662.5
1991	2,431.5	2,488.6	737.7	814.6	208.3	282.1	3,377.5	3,585.3
1992	2,990.4	3,070.6	291.7	289.3	100.1	100.1	3,382.2	3,460.0
1993	1,563.1	1,492.5	300.3	292.8	441.2	357.6	2,304.6	2,142.9
1994	2,815.4	2,239.7	381.9	247.5	521.0	428.0	3,718.3	2,915.2
1995		5,013.7		670.1		772.8		6,456.6
1996		8,107.1		660.6		771.7		9,539.4
1997		6,086.9		366.4		666.2		7,119.5
1998		3,481.3		240.3		445.2		4,166.8
1999		1,573.2		75.7		217.0		1,865.9
2000		2,516.2		124.1		214.7		2,855.0
2001		1,075.2		49.4		206.4		1,331.0
2002		391.6		8.1		53.0		452.7
2003		1,203.7		27.7		113.0		1,344.4
2004		1,926.9		21.3		183.2		2,131.4
2005		2,270.2		49.6		290.3		2,610.1
2006		2,201.6		30.0		91.1		2,322.7
2007		4,469.3		27.5		382.9		4,879.7
2008		4,515.8		29.9		416.8		4,962.4
2009		2,315.7		MA & NH combined		185.6		2,501.2
2010		5,604.3		35.1		501.4		6,140.8
2011		5,569.7		196.4		631.5		6,397.5
*2012		2,211.4		77.8		187.8		2,476.9
*2013		255.5		20.3		31.3		307.1

Table 1b. Price and value of U.S. Commercial landings (mt) of northern shrimp in the Gulf of Maine. (*2012 and 2013 data are preliminary.)

Year	Price $/Lb	Value $
1958	0.32	1,532
1959	0.29	5,002
1960	0.23	20,714
1961	0.20	13,754
1962	0.15	57,382
1963	0.12	66,840
1964	0.12	112,528
1965	0.12	245,469
1966	0.14	549,466
1967	0.12	871,924
1968	0.11	1,611,425
1969	0.12	3,478,910
1970	0.20	4,697,418
1971	0.19	4,653,202
1972	0.19	4,586,484
1973	0.27	5,657,347
1974	0.32	5,577,465
1975	0.26	3,062,721
1976	0.34	764,094
1977	0.55	458,198
1978	0.24	1,758
1979	0.33	320,361
1980	0.65	478,883
1981	0.64	1,516,521
1982	0.60	2,079,109
1983	0.67	2,312,073
1984	0.49	3,474,351
1985	0.44	3,984,563
1986	0.63	6,451,207
1987	1.10	12,740,583
1988	1.10	7,391,778
1989	0.98	7,177,660
1990	0.72	7,351,421
1991	0.91	7,208,839
1992	0.99	7,547,942
1993	1.07	5,038,053
1994	0.75	4,829,107
1995	0.90	12,828,031
1996	0.73	15,341,506
1997	0.79	12,355,873
1998	0.96	8,811,939
1999	0.91	3,762,044
2000	0.79	4,968,656
2001	0.86	2,534,095
2002	1.08	1,077,534
2003	0.87	2,590,917
2004	0.44	2,089,636
2005	0.57	3,261,648
2006	0.37	1,885,978
2007	0.38	4,087,121
2008	0.49	5,407,374
2009	0.40	2,216,411
2010	0.52	6,994,107
2011	0.75	10,625,534
*2012	0.95	5,212,137
*2013	1.81	1,223,045

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

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1985 Season, 166 days, Dec 1 - May 15								
Maine	335.7	851.8	1,095.5	525.1	116.8	21.5	0.0	2,946.4
Mass.	91.7	283.9	238.3	239.3	57.8	57.0	0.8	968.8
N.H.	67.0	86.2	50.4	11.6	1.3		0.2	216.7
Total	494.4	1,221.9	1,384.2	776.0	175.9	78.5	1.0	4,131.9
1986 Season, 196 days, Dec 1 - May 31, June 8-21								
Maine	346.9	747.8	1,405.3	415.4	104.2	149.2	99.4	3,268.2
Mass.	154.3	213.4	221.2	200.7	111.2	84.8	150.7	1,136.3
N.H.	57.7	75.9	70.8	14.2	1.3	0.0	10.6	230.5
Total	558.9	1,037.1	1,697.3	630.3	216.7	234.0	260.7	4,635.0
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
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		759.9	1,534.4	221.9				2,516.2
Mass.		25.9	86.0	12.2				124.1
N.H.		40.6	133.7	40.4				214.7
Total	0.0	826.4	1,754.0	274.6	0.0	0.0	0.0	2,855.0

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

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
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		0.002		49.4
N.H.		127.9	78.6	conf	conf			206.4
Total	0.0	742.2	520.3	38.4	29.8	0.3	0.0	1,331.0
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			306.8	84.8				391.6
Mass.			8.1	conf				8.1
N.H.			38.6	14.4				53.0
Total	0.0	0.0	353.5	99.1	0.0	0.0	0.0	452.7
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.		conf	21.3	conf				21.3
N.H.		27.3	94.8	61.1				183.2
Total	1.8	553.5	1,061.1	507.5	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	369.4	903.2	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	431.0	1,103.6	976.0	0.0	0.0	0.01	2,610.1
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	144.1	691.7	896.9	350.8	118.0			2,201.6
Mass.	conf	conf	30.0	conf	conf			30.0
N.H.	3.4	27.9	9.6	50.3	conf			91.1
Total	147.5	719.6	936.5	401.1	118.0	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.	conf	27.5	conf	conf				27.5
N.H.	52.5	222.6	81.6	26.1	conf			382.9
Total	814.4	1,730.6	1,672.0	508.1	154.2	0.4	0.0	4,879.7
2008 Season, 152 days, Dec 1 - Apr 30								
Maine	408.5	1,053.7	2,020.4	983.8	49.3		0.1	4,515.8
Mass.	conf	conf	15.4	14.5				29.9
N.H.	94.2	123.7	161.6	37.4	conf			416.8
Total	502.6	1,177.4	2,197.3	1,035.7	49.3	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	conf	112.9	72.6	conf	conf			185.6
Total	134.6	708.8	1,060.8	560.1	34.9	1.8	0.2	2,501.2
2010 Season, 156 days, Dec 1 - May 5								
Maine	263.4	1,683.1	2,914.5	515.6	194.3	33.0	0.4	5,604.3
Mass.	conf	16.9	18.2	conf	conf			35.1
N.H.	107.3	152.4	200.0	14.2	27.4	conf		501.4
Total	370.7	1,852.5	3,132.7	529.8	221.7	33.0	0.4	6,140.8
2011 Season, 90 days, Dec 1 - Feb 28								
Maine	722.7	2,572.2	2,274.3	0.5				5,569.7
Mass.	20.8	100.9	74.7					196.4
N.H.	93.1	304.0	234.4					631.46
Total	836.6	2,977.0	2,583.4	0.5	0.0	0.0	0.0	6,397.5
***2012** Season, Trawling Mon,Wed,Fri, Jan 2 - Feb 17 (21 days); Trapping Feb 1-17 (17 days)								
Maine	0.5	1,130.1	1,080.2	0.5				2,211.4
Mass.		58.4	19.4					77.8
N.H.		119.2	68.6					187.8
Total	0.5	1,307.7	1,168.2	0.5	0.0	0.0	0.0	2,476.9
***2013** Season, Trawling 3 to 7 days/wk, Jan 23 - Apr 12 (54 days); Trapping 6 or 7 days/wk, Feb 5 - Apr 12 (62 days)								
Maine		54.2	167.2	33.6	0.5			255.5
Mass.		4.3	8.9	7.2	conf			20.3
N.H.		14.5	13.5	3.3	conf			31.3
Total	0.0	72.9	189.5	44.1	0.5	0.0	0.0	307.1

conf = Confidential data were included in an adjacent month.

* 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
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off									
Trawl		731.1	1,354.8	163.6				2,249.47	89%
Trap		28.9	179.6	58.3				266.7	11%
Total	0.0	759.9	1,534.4	221.9	0.0	0.0	0.0	2,516.2	
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		conf	132.6	259.0				391.6	17%
Total	75.0	369.4	903.2	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	conf	16.7	163.1	93.9	0.9			274.6	12%
Total	144.1	691.7	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	

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	% of total
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	conf	64.1	339.6	380.4	6.7			790.8	18%
Total	408.5	1,053.7	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	1,488.3	2,091.1	326.3	194.3	33.0	0.4	4,396.7	78%
Trap	conf	194.8	823.4	189.3	conf			1,207.6	22%
Total	263.4	1,683.1	2,914.5	515.6	194.3	33.0	0.4	5,604.3	
2011 Season, 90 days, Dec 1 - Feb 28									
Trawl	720.8	2,194.5	1,728.5	0.5				4,644.4	83%
Trap	1.9	377.7	545.8					925.3	17%
Total	722.7	2,572.2	2,274.3	0.5	0.0	0.0	0.0	5,569.7	
***2012** Season, Trawling Mon,Wed,Fri, Jan 2 - Feb 17 (21 days); Trapping Feb 1-17 (17 days)									
Trawl	0.5	1,130.1	887.1	0.5				2,018.3	91%
Trap			193.1					193.1	9%
Total	0.5	1,130.1	1,080.2	0.5	0.0	0.0	0.0	2,211.4	
***2013** Season, Trawl 2-7 days/wk, Jan 23-Apr 12 (54 days); Trap 6-7 days/wk, Feb 5-Apr 12 (62 days)									
Trawl		54.2	154.6	31.4	0.5			240.7	94%
Trap			12.5	2.2	conf			14.8	6%
Total	0.0	54.2	167.2	33.6	0.5	0.0	0.0	255.5	

conf = Confidential data were included in an adjacent month.
* Preliminary data

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

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1985 Season, 166 days, Dec 1 - May 15								
Maine	552	1,438	1,979	1,198	260	35		5,462
Mass.	127	269	224	231	92	73		1,016
N.H.	118	135	78	26	22			379
Total	797	1,842	2,281	1,455	374	108	0	6,857
1986 Season, 183 days, Dec 1 - May 31								
Maine	590	1,309	2,798	831	224	133	68	5,953
Mass.	128	235	225	320	194	133	159	1,394
N.H.	156	163	165	51	3		17	555
Total	874	1,707	3,188	1,202	421	266	244	7,902
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	212	12,497
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	0	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	0	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	0	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	0	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	0	7,798

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
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	0	0	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	0	0	5,990
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	0	0	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	0	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	0	10,734
1998 Season, 152 days, Dec 1 - May 31, 1 day per week 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	1,087	1,964	1,983	929	432	212	0	6,606
1999 Season, 152 days, Dec 1 - May 31, 1 day per week 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	0	3,811
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		897	2,494	647				4,038
Mass.		33	117	32	1			183
N.H.		45	201	87				333
Total	0	975	2,812	766	1	0	0	4,554

Table 4 continued – Trips by season, state, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 15 off, experimental offshore fishery in May								
Maine		1,683	1,551	177	43	6		3,460
Mass.		111	48	10		1		170
N.H.		303	200	conf	conf			503
Total	0	2,097	1,799	187	43	7	0	4,133
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			799	299				1,098
Mass.			31	conf				31
N.H.			119	56				175
Total	0	0	949	355	0	0	0	1,304
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		1,114	1,582	1			2	2,699
Mass.		41	50					91
N.H.		81	151					232
Total	0	1,236	1,783	1	0	0	2	3,022
2004 Season, 40days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	7	647	1,197	482	13	14	6	2,366
Mass.		conf	56	conf				56
N.H.		46	147	66				259
Total	7	693	1,400	548	13	14	6	2,681
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	140	667	1,305	1,255	0	0	1	3,368
Mass.	15	18	49	23				105
N.H.	24	76	216	77				393
Total	179	761	1,570	1,355	0	0	1	3,866
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	148	585	947	530	101			2,311
Mass.	conf	conf	58	conf	conf			58
N.H.	5	23	19	62	conf			109
Total	153	608	1,024	592	101	0	0	2,478
2007 Season, 151 days, Dec 1 - Apr 30								
Maine	437	1,102	1,514	669	136	1	3	3,862
Mass.	conf	45	conf	conf				45
N.H.	26	115	71	44	conf			256
Total	463	1,262	1,585	713	136	1	3	4,163
2008 Season, 152 days, Dec 1 - Apr 30								
Maine	418	1,291	2,076	1,286	102	0	9	5,182
Mass.	conf	conf	25	13				38
N.H.	63	141	125	38	conf			367
Total	481	1,432	2,226	1,337	102	0	9	5,587

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2009 Season, 180 days, Dec 1 - May 29								
Maine	134	785	1,122	739	47	5	1	2,833
Mass.& NH	conf	107	62	conf	conf			169
Total	134	892	1,184	739	47	5	1	3,002
2010 Season, 156 days, Dec 1 - May 5								
Maine	241	1,561	2,593	911	185	29	1	5,521
Mass.	conf	26	23	conf	conf			49
N.H.	54	127	151	21	56	conf		409
Total	295	1,714	2,767	932	241	29	1	5,979
2011 Season, 90 days, Dec 1 - Feb 28								
Maine	599	2,880	2,875	1				6,355
Mass.	28	92	73	0	0			193
N.H.	108	241	198					547
Total	735	3,213	3,146	1	0	0	0	7,095
***2012** Season, Trawling Mon,Wed,Fri, Jan 2 - Feb 17 (21days); Trapping Feb 1-17 (17 days)								
Maine	1	1,302	2,000	1				3,304
Mass.		74	42					116
N.H.		129	99					228
Total	1	1,505	2,141	1	0	0	0	3,648
***2013** Season, Trawl 2-7 days/wk, Jan 23-Apr 12 (54 days); Trap 6-7 days/wk, Feb 5-Apr 12 (62 days)								
Maine		166	790	196	7			1,159
Mass.		8	30	30	conf			68
N.H.		21	59	15	conf			95
Total	0	195	879	241	7	0	0	1,322

conf = Confidential data were included in an adjacent month.
* Preliminary data

Table 5. Distribution of fishing trips in the Maine northern shrimp fishery by season, gear type, and month.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	%
2000									
Trawl		818	2,073	462				3,353	97%
Trap		79	421	185				685	20%
Total	0	897	2,494	647	0	0	0	4,038	
2001									
Trawl		1,500	1,214	112	43	6		2,875	83%
Trap		183	337	65				585	17%
Total	0	1,683	1,551	177	43	6	0	3,460	
2002									
Trawl			595	236				831	76%
Trap			204	63				267	24%
Total	0	0	799	299	0	0	0	1,098	
2003									
Trawl		850	1,081	1			2	1,934	72%
Trap		264	501					765	28%
Total	0	1,114	1,582	1	0	0	2	2,699	
2004									
Trawl	7	566	965	382	13	14	6	1,953	83%
Trap		81	232	100				413	17%
Total	7	647	1,197	482	13	14	6	2,366	
2005									
Trawl	140	647	953	778			1	2,519	75%
Trap		conf	372	477				849	25%
Total	140	647	1,325	1,255	0	0	1	3,368	
2006									
Trawl	145	490	563	273	88			1,559	67%
Trap	conf	98	384	257	13			752	33%
Total	145	588	947	530	101	0	0	2,311	
2007									
Trawl	425	977	921	349	119	1	3	2,795	72%
Trap	12	125	593	320	17			1,067	28%
Total	437	1,102	1,514	669	136	1	3	3,862	

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	%
2008									
Trawl	414	1,062	1,393	661	51	0	9	3,590	69%
Trap	conf	233	683	625	51			1,592	31%
Total	414	1,295	2,076	1,286	102	0	9	5,182	
2009									
Trawl	130	705	673	381	32	5	1	1,927	68%
Trap	4	80	449	358	15			906	32%
Total	134	785	1,122	739	47	5	1	2,833	
2010									
Trawl	238	1,230	1,512	447	157	29	1	3,614	65%
Trap	conf	334	1,081	492	conf			1,907	35%
Total	238	1,564	2,593	939	157	29	1	5,521	
2011									
Trawl	577	2,068	1,692	1				4,338	68%
Trap	22	812	1,183					2,017	32%
Total	599	2,880	2,875	1	0	0	0	6,355	
***2012**									
Trawl	1	1,302	1,032	1				2,336	71%
Trap			968					968	29%
Total	1	1,302	2,000	1	0	0	0	3,304	
***2013**									
Trawl		166	621	164	conf			951	82%
Trap			169	39	conf			208	18%
Total	0	166	790	203	0	0	0	1,159	

conf = Confidential data were included in an adjacent month.
* Preliminary data

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	124	112	236	6	14	256
2011	172	143	311	12	19	342
*2012	163	131	293	14	17	324
*2013	122	46	168	16	14	198

note that some boats reported both trapping and trawling

* preliminary

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

Season	Maine pounds per hour towing			Pounds/trip	Trawl lbs/trip
	Inshore (<55F)	Offshore (>55F)	Combined		
1991	94	152	140	992	
1992	132	93	117	978	
1993	82	129	92	767	
1994	139	149	141	1,073	
1995	172	205	193	1,360	
1996	340	203	251	1,784	
1997	206	192	194	1,462	
1998	158	151	154	1,391	
1999	148	147	147	1,079	
2000	279	224	272	1,382	1,475
2001	100	135	109	710	752
2002	223	91	194	765	854
2003	174	215	182	981	1,102
2004	361	310	351	1,753	2,006
2005	235	212	228	1,488	1,621
2006	572	345	499	2,066	2,616
2007	531	477	507	2,584	3,129
2008	350	327	343	1,958	2,302
2009	400	315	370	1,837	2,231
2010	424	354	401	2,264	2,671
2011	334	435	347	1,988	2,376
*2012	407	313	399	1,497	1,879
*2013	118	78	110	512	579

* 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	(samples lost)			
2011	**17.86**	50	14.88	21.40	**4.20**	32	3.24	5.38
2012	**7.50**	50	6.07	9.23	**1.89**	42	1.53	2.30
***2013**	**1.69**	46	1.09	2.46				

*2013 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				
Year	N Tows	Age-1.5 Number	>22 mm** Number	>22 mm Weight (kg)	Total Number	Total Weight (kg)
1984	37	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	44	316	3.2	830	8.6
2012	49	7	81	0.9	138	2.5
2013	40	1	24	0.3	27	1.0
Mean	41	367	543	6.0	1,458	12.9
Median	41	312	377	4	1154	10
1984-93						
Mean	42	382	649	7.1	1,435	14.1
Median	43	337	611	7.0	1,401	14.1

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

Table 10. Input data for CSA models. Data sources described in text.

Survey Year*	Abundance Indices		Mean weights (kg)		Selectivity	Total Catch	Mean wt (kg)
	New Recruits	Full Recruits	New Recruits	Full Recruits	ratio	Millions*	in Catch
1984	448	479	0.006	0.008	0.88	356	0.012
1985	612	914	0.008	0.009	0.89	369	0.013
1986	533	849	0.007	0.010	0.93	424	0.012
1987	483	767	0.007	0.010	1.00	220	0.014
1988	460	388	0.005	0.009	0.73	296	0.011
1989	701	818	0.007	0.009	0.92	437	0.011
1990	512	908	0.008	0.010	0.95	335	0.011
1991	374	612	0.007	0.011	1.00	268	0.013
1992	314	444	0.007	0.010	1.00	187	0.011
1993	410	321	0.005	0.008	1.00	263	0.011
1994	369	364	0.006	0.008	0.84	627	0.010
1995	486	653	0.007	0.010	1.00	865	0.011
1996	258	349	0.007	0.010	1.00	716	0.010
1997	257	267	0.005	0.009	0.92	361	0.012
1998	217	227	0.006	0.009	0.92	207	0.009
1999	137	175	0.007	0.009	0.95	261	0.011
2000	276	288	0.005	0.009	1.00	142	0.009
2001	172	196	0.007	0.008	0.92	47	0.010
2002	551	373	0.004	0.008	1.00	128	0.010
2003	223	230	0.006	0.008	0.85	221	0.010
2004	293	406	0.007	0.010	0.72	240	0.011
2005	1,295	1,232	0.005	0.009	0.63	203	0.011
2006	3,878	4,024	0.006	0.008	0.94	548	0.009
2007	323	421	0.007	0.009	0.88	490	0.010
2008	562	847	0.007	0.010	0.97	222	0.011
2009	514	723	0.006	0.011	0.91	514	0.012
2010	491	539	0.006	0.009	0.95	605	0.011
2011	318	344	0.006	0.008	0.91	266	0.009
2012	45	73	0.008	0.010	1.00	28	0.011
2013	7	19	0.010	0.012	0.91		

* Survey Year data are applied to the following Fishing Year

Table 11a. Summary of results from Collie-Sissenwine Analysis assuming M=0.25.

Fishing Season	New Recruits (millions)	Fully-Recruited (millions)	F (NR+FR)	Biomass (1000 mt)	Exploitation Rate
1985	641	590	0.39	8.9	29%
1986	689	648	0.37	11.3	28%
1987	523	719	0.48	11.2	34%
1988	385	598	0.29	8.9	22%
1989	651	573	0.32	8.1	24%
1990	703	695	0.43	10.6	31%
1991	439	707	0.40	10.8	29%
1992	313	600	0.40	8.7	29%
1993	273	477	0.33	6.7	25%
1994	442	421	0.42	5.5	30%
1995	931	443	0.71	9.1	46%
1996	962	526	1.03	11.5	58%
1997	651	413	1.35	8.3	67%
1998	441	215	0.94	4.4	55%
1999	313	199	0.60	3.6	40%
2000	280	219	0.87	3.9	52%
2001	262	163	0.47	2.9	33%
2002	192	207	0.14	3.0	12%
2003	409	269	0.24	3.9	19%
2004	313	416	0.42	5.2	30%
2005	639	374	0.31	8.0	24%
2006	1362	579	0.13	12.3	10%
2007	1104	1333	0.29	17.8	22%
2008	295	1419	0.39	14.5	29%
2009	420	907	0.21	12.1	17%
2010	418	839	0.61	11.4	41%
2011	371	531	1.34	7.1	67%
2012	167	184	1.77	2.6	76%
2013	29	47	0.53	0.7	37%
2014	7	35		0.5	
Overall mean	488	512	0.56	7.8	35%
1985-94 mean	506	603	0.38	9.1	28%
1985-94 maximum			0.48		30%

Table 11b. Summary of results from Collie-Sissenwine Analysis assuming M=0.6.

Fishing Season	New Recruits (millions)	Fully-Recruited (millions)	F (NR+FR)	Biomass (1000 mt)	Exploitation Rate
1985	1,491	1,360	0.18	20.6	12%
1986	1,804	1,307	0.17	25.8	12%
1987	1,355	1,440	0.22	24.5	15%
1988	963	1,228	0.14	19.5	10%
1989	1,759	1,043	0.15	17.5	11%
1990	1,957	1,324	0.19	24.2	13%
1991	1,168	1,484	0.18	24.6	13%
1992	797	1,213	0.19	18.6	13%
1993	668	910	0.17	13.7	12%
1994	1,033	731	0.22	10.8	15%
1995	1,747	778	0.39	16.6	25%
1996	1,569	936	0.59	19.5	35%
1997	915	761	0.79	13.5	43%
1998	797	417	0.49	8.2	30%
1999	630	409	0.30	7.3	20%
2000	526	421	0.44	7.4	28%
2001	651	333	0.21	6.7	14%
2002	498	438	0.07	6.9	5%
2003	1,044	479	0.12	8.3	8%
2004	752	743	0.22	10.6	15%
2005	1,722	660	0.14	18.2	10%
2006	4,829	1,134	0.05	35.4	3%
2007	3,412	3,124	0.12	46.8	8%
2008	715	3,190	0.18	32.9	13%
2009	1,026	1,788	0.11	25.2	8%
2010	875	1,383	0.35	20.1	23%
2011	612	870	0.74	11.6	41%
2012	285	388	0.71	5.0	40%
2013	67	182	0.16	2.3	11%
2014	16	116		1.5	

Table 12. Comparison of diagnostics from CSA models assuming M=0.25 and M=0.60. Values shown are averages of time series for each metric. Percent bias reflects accuracy of estimates, CV (coefficient of variation) reflects precision of estimates, Mohn's rho characterizes severity of retrospective pattern, AIC indicates overall model fit with lower values indicating better fit.

		Abundance (millions)			
Diagnostic	Assumed M	New Recruit	Full Recruit	Biomass	F
Bias (%)	0.25	-0.3	-2.0	-1.6	15.1
	0.60	-0.7	-1.6	-1.4	21.0
CV (%)	0.25	49.3	45.2	27.7	35.9
	0.60	56.0	52.4	40.2	42.4
Mohn's rho (%)	0.25	97.0	141.0	123.2	-45.3
	0.60	333.5	373.5	363.7	-73.2

Goodness of Fit	AIC
M=0.25	-36.9
M=0.6	-44.6

Table 13. Input values and summary of results from base model of surplus production model (ASPIC) run using all survey indices.

	ASPIC Model Input					ASPIC Model Results			
Year	NEFSC Fall	ME Summer (kg/tow)	ASMFC Summer Shrimp (kg/tow)	ME-NH Spring	Catch (MT)	Biomass (000s of MT)	F	B/Bmsy	F/Fmsy
1968	3.20	45.80			6,610	51.96	0.14	2.04	0.71
1969	2.70	31.20			12,824	46.11	0.32	1.81	1.65
1970	3.70	40.80			10,670	36.32	0.32	1.43	1.70
1971	3.00	9.40			11,130	30.06	0.42	1.18	2.19
1972	3.30	7.00			11,095	23.74	0.55	0.93	2.87
1973	1.90	7.80			9,405	17.27	0.66	0.68	3.45
1974	0.80	4.90			7,945	11.76	0.89	0.46	4.68
1975	0.90	6.70			5,287	6.60	1.19	0.26	6.23
1976	0.60	4.80			1,022	2.85	0.36	0.11	1.88
1977	0.20	1.60			381	2.86	0.12	0.11	0.62
1978	0.40	3.20			3	3.62	0.00	0.14	0.00
1979	0.50	4.40			439	5.13	0.08	0.20	0.39
1980	0.50	2.70			333	6.67	0.04	0.26	0.23
1981	1.50	3.00			1,074	8.83	0.11	0.35	0.58
1982	0.30	2.00			1,574	10.76	0.14	0.42	0.71
1983	1.00	4.20			1,574	12.61	0.12	0.50	0.60
1984	1.90		10.47		3,227	14.85	0.21	0.58	1.11
1985	1.60		17.69		4,132	15.69	0.26	0.62	1.38
1986	2.50		19.61		4,635	15.70	0.30	0.62	1.58
1987	1.70		15.40		5,266	15.16	0.36	0.60	1.91
1988	1.20		12.76		3,036	13.83	0.21	0.54	1.12
1989	1.81		16.95		3,315	14.71	0.22	0.58	1.15

Table 13 continued - Input values and summary of results from base model of surplus production model (ASPIC) run.

	ASPIC Model Input					ASPIC Model Results			
	NEFSC Fall	ME Summer (kg/tow)	ASMFC Summer Shrimp (kg/tow)	ME-NH Spring	Catch (MT)	Biomass (000s of MT)	F	B/Bmsy	F/Fmsy
1990	2.04		18.12		4,663	15.44	0.31	0.61	1.62
1991	0.44		11.68		3,585	14.83	0.24	0.58	1.25
1992	0.41		9.43		3,460	15.28	0.22	0.60	1.16
1993	1.85		9.14		2,143	15.94	0.13	0.63	0.66
1994	2.24		8.69		2,915	18.12	0.15	0.71	0.81
1995	1.22		13.29		6,457	19.73	0.35	0.77	1.81
1996	0.90		8.77		9,539	17.78	0.65	0.70	3.39
1997	1.12		7.73		7,120	12.21	0.71	0.48	3.73
1998	1.99		6.33		4,167	8.15	0.58	0.32	3.04
1999	2.32		5.78		1,866	6.33	0.29	0.25	1.51
2000	1.28		6.39		2,855	6.62	0.46	0.26	2.41
2001	0.63		4.33		1,331	5.85	0.21	0.23	1.12
2002	1.70		9.16		453	6.59	0.06	0.26	0.31
2003	1.08		5.45	4.16	1,344	8.59	0.14	0.34	0.75
2004	1.58		10.27	3.87	2,131	10.15	0.20	0.40	1.05
2005	2.77		23.38	7.81	2,610	11.24	0.22	0.44	1.18
2006	6.64		65.99	10.99	2,323	12.05	0.18	0.47	0.96
2007	4.13		11.51	10.70	4,880	13.36	0.38	0.52	2.01
2008	3.05		16.77	15.42	4,962	12.11	0.44	0.48	2.31
2009			15.44	9.65	2,501	10.49	0.23	0.41	1.21
2010			13.94	15.95	6,141	11.24	0.64	0.44	3.38
2011			8.47	17.86	6,398	8.05	1.18	0.32	6.17
2012			2.50	7.50	2,477	3.49	0.90	0.14	4.70
2013			1.00	1.69	307	2.04	0.13	0.08	0.70
2014						2.57		0.10	
Average:	1.77	11.22	12.88	9.60	4,165	13.52	0.35		

Table 14. 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 1000 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

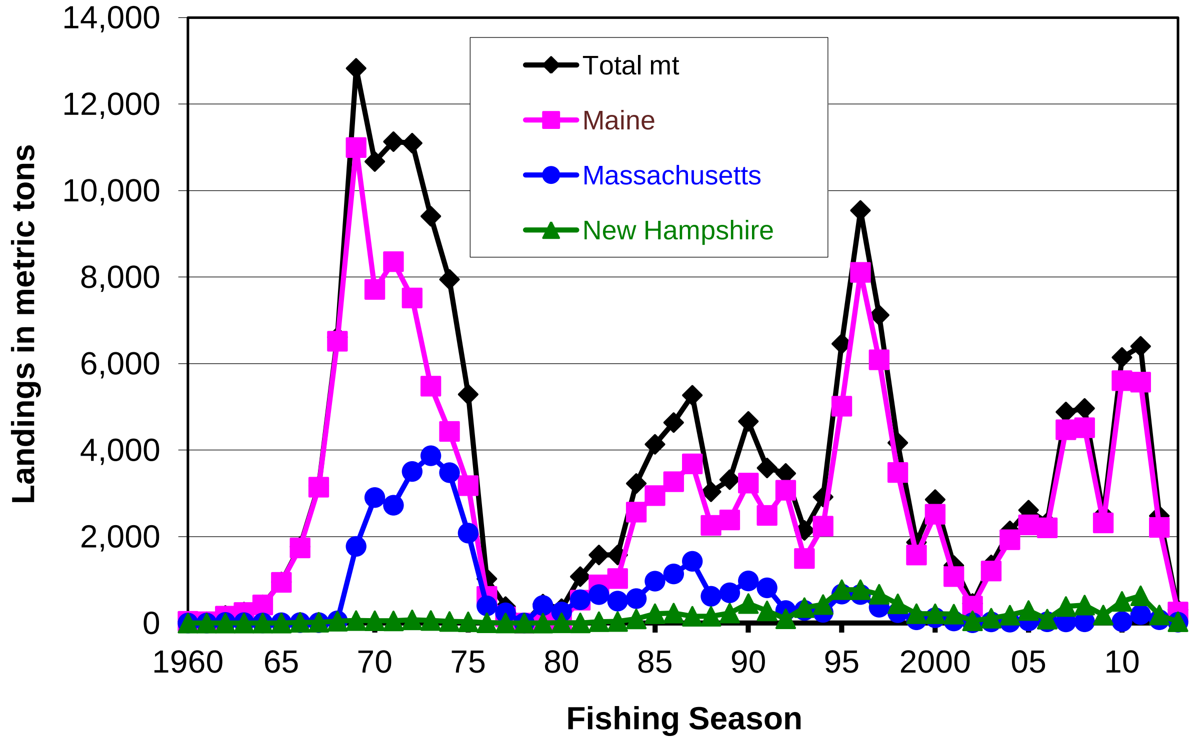


Figure 1. Gulf of Maine northern shrimp landings by season and state.
MA landings are combined with NH landings in 2009 to preserve confidentiality.

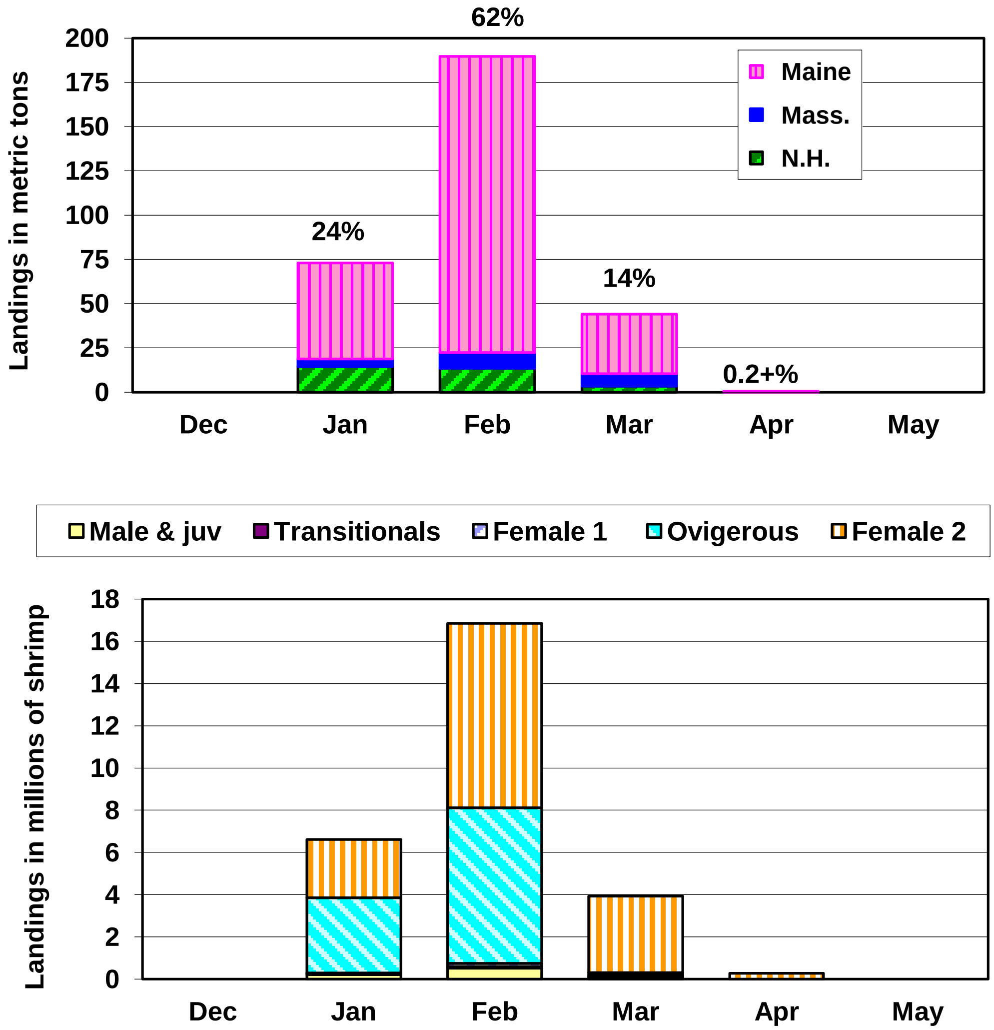


Figure 2. Gulf of Maine northern shrimp landings by month and development stage for 2013 (preliminary data). Landings are in metric tons by state (above), and in millions of shrimp by development stage (below).

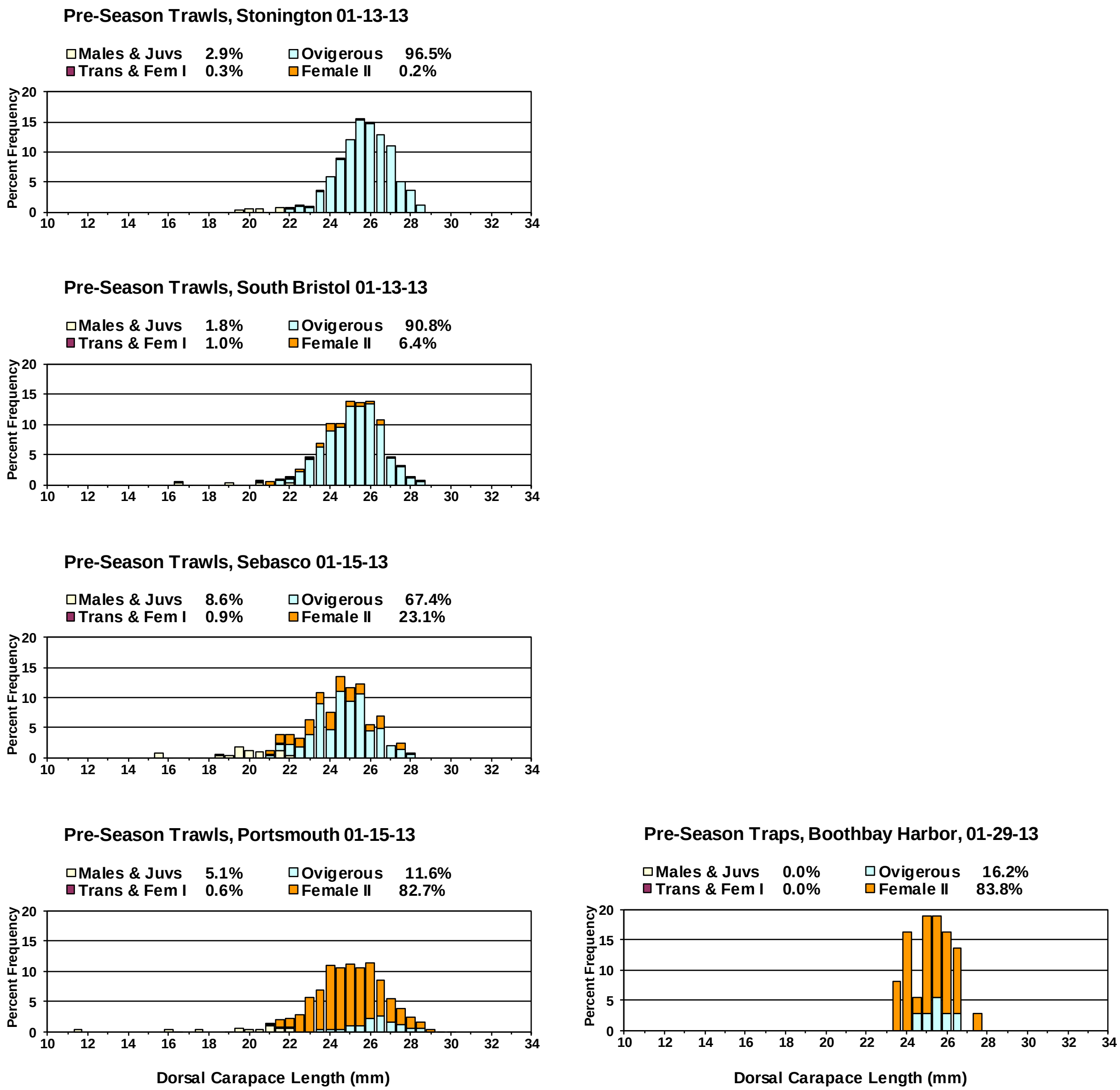


Figure 3a. Relative length-frequency distributions from samples of northern shrimp from pre-season tows (left) and traps (right).

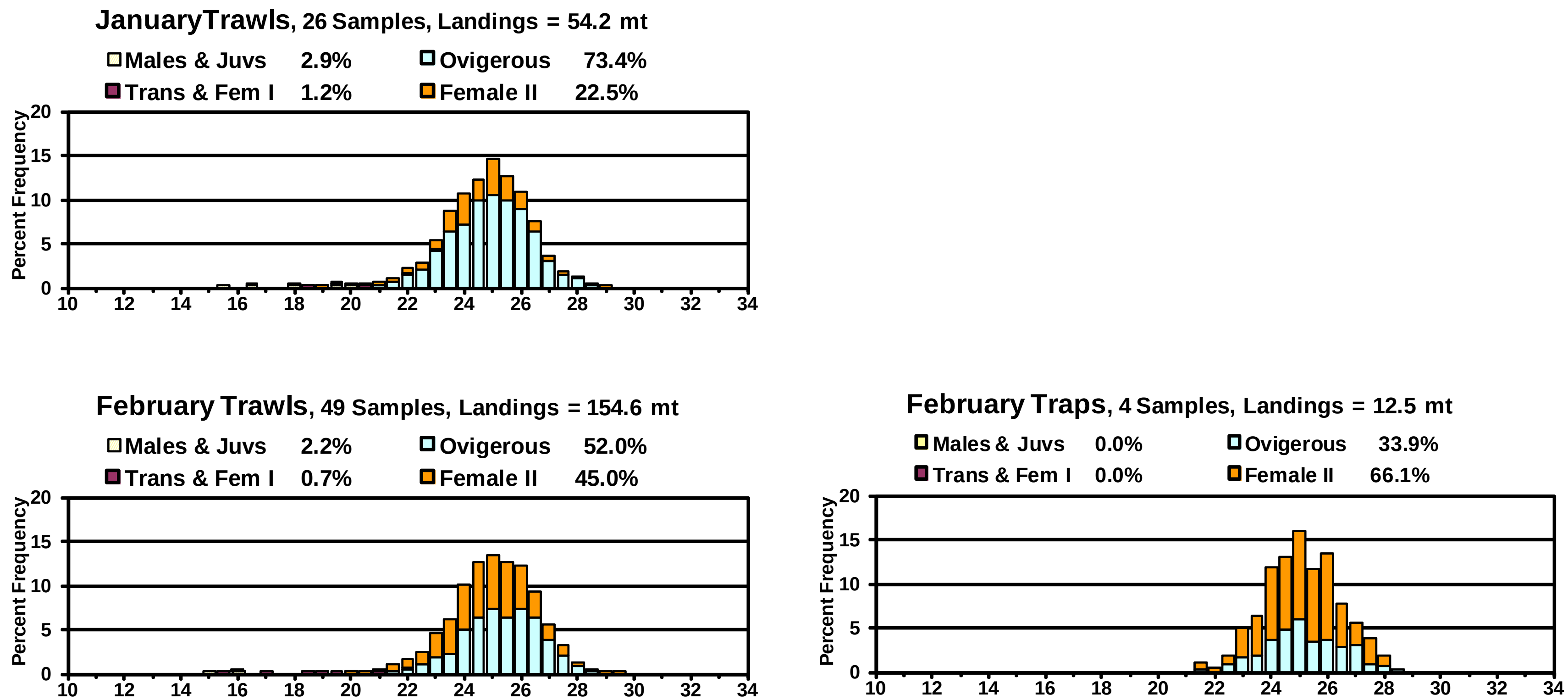


Figure 3b. Relative length-frequency distributions from samples of Maine northern shrimp catches during the 2013 season by month. Landings are preliminary.

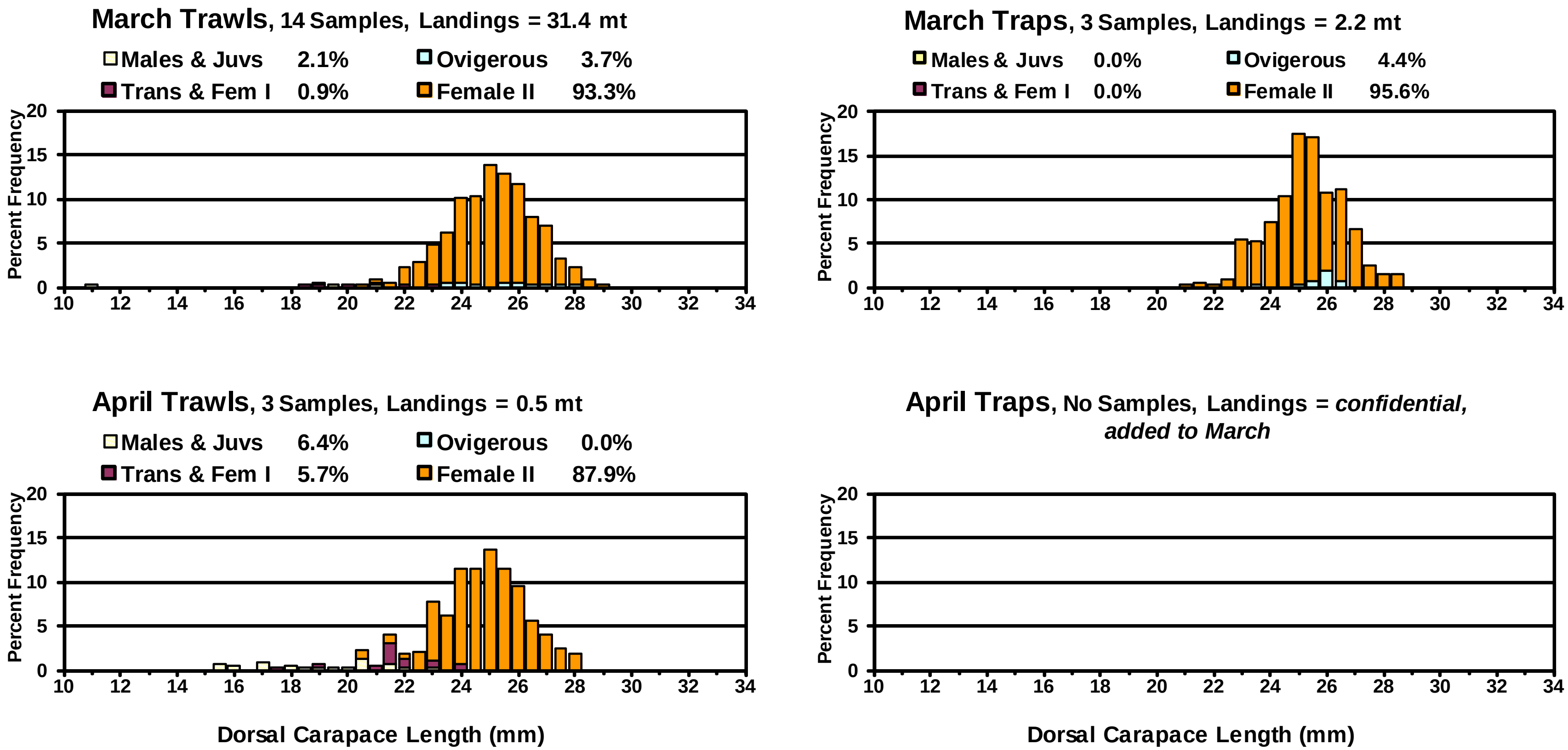


Figure 3b continued. Relative length-frequency distributions.

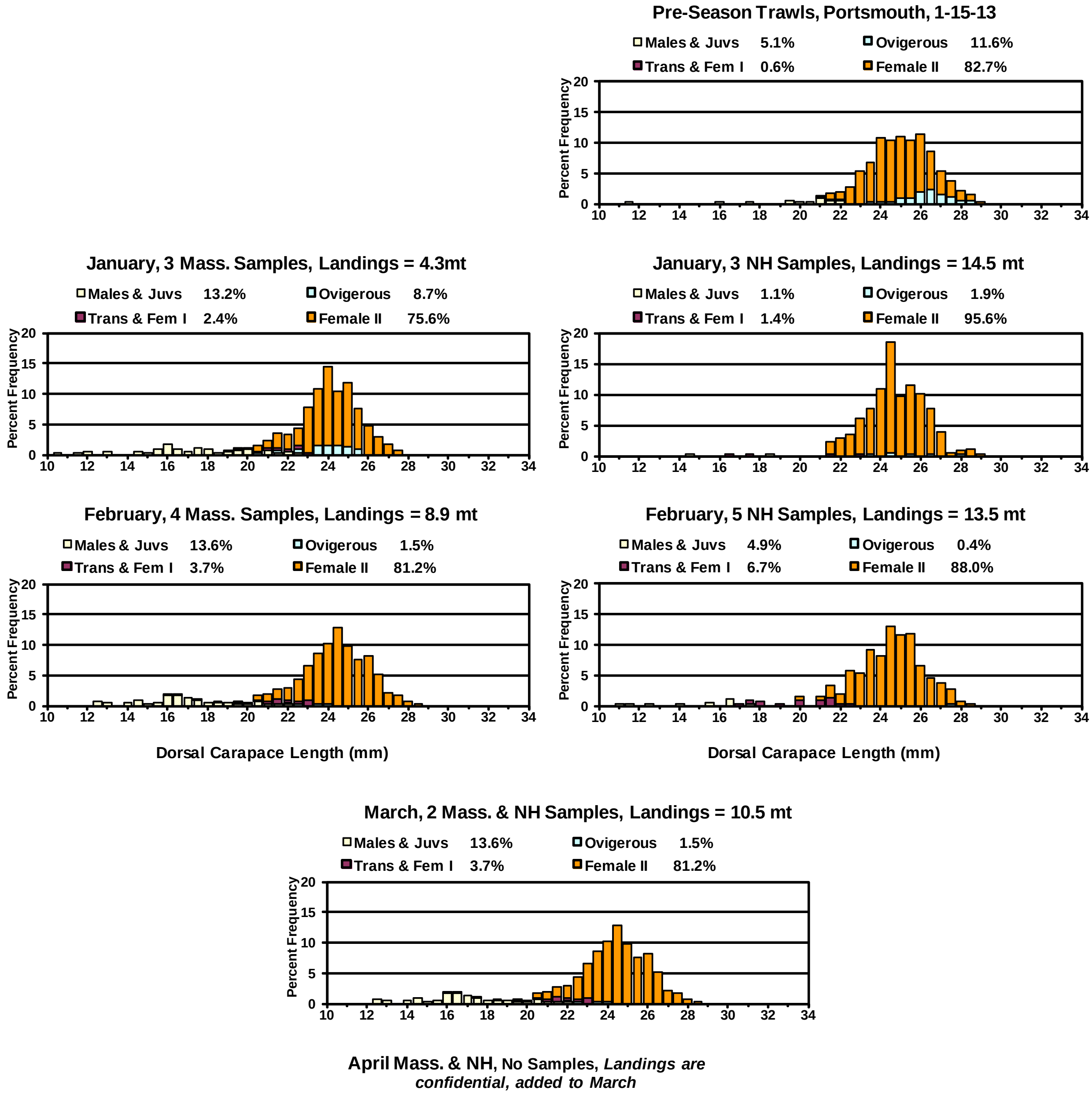


Figure 4. Relative length-frequency distributions from samples of Massachusetts (left) and New Hampshire (right) northern shrimp catches during the 2013 season by month. Landings are preliminary.

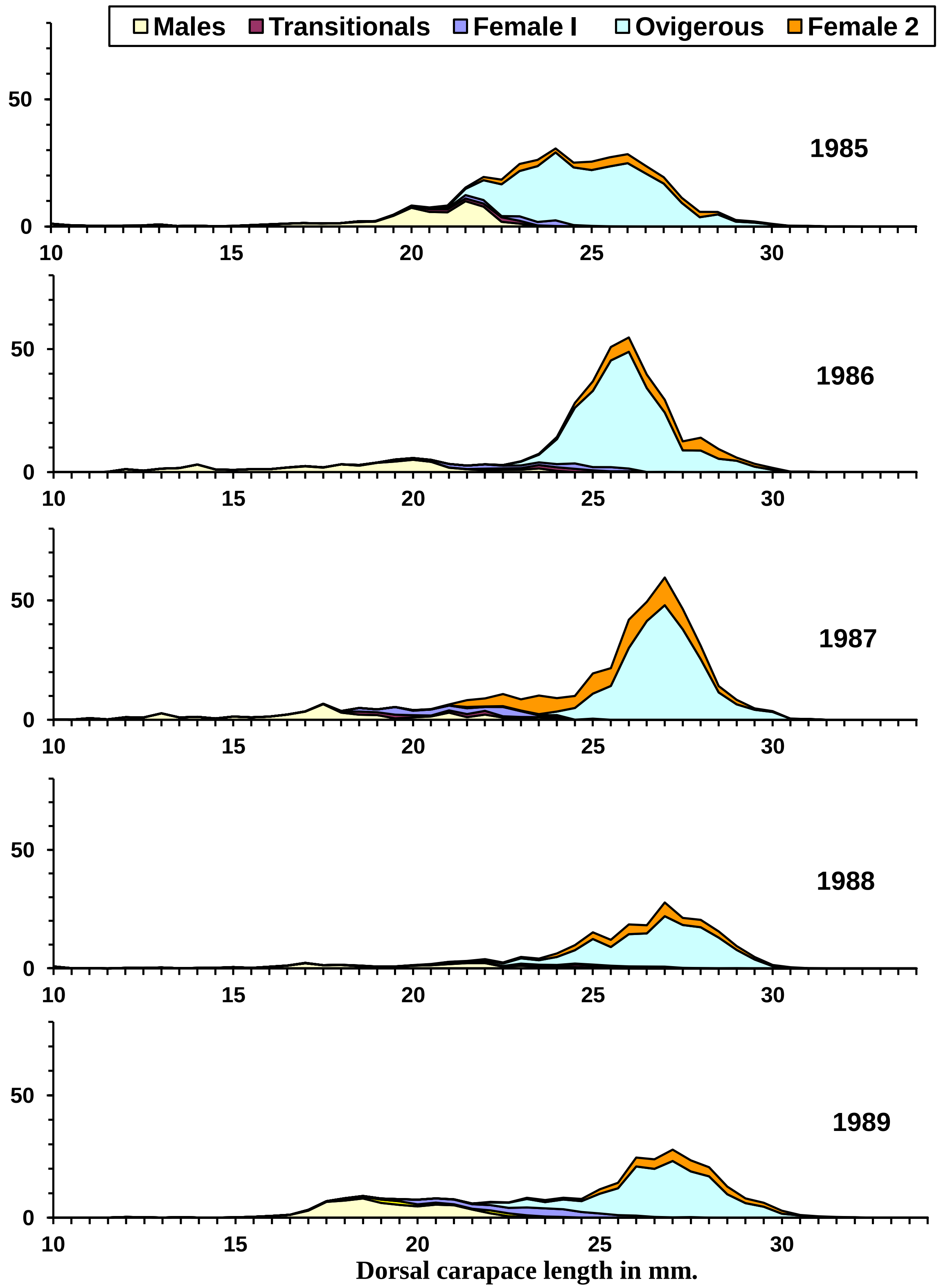


Figure 5. Gulf of Maine northern shrimp landings in estimated numbers of shrimp, by length, development stage, and fishing season.

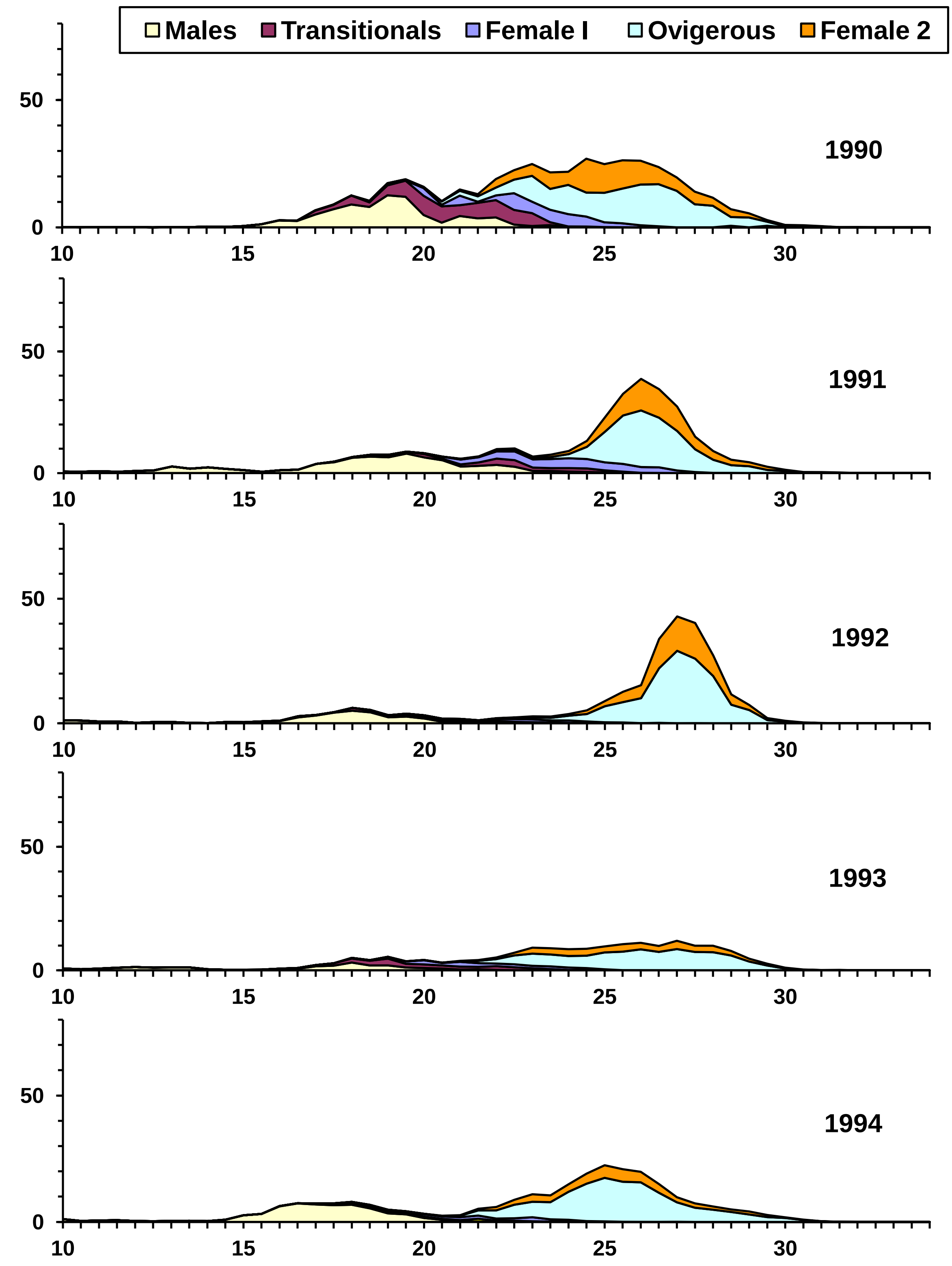


Figure 5 continued –Landings in estimated numbers of shrimp.

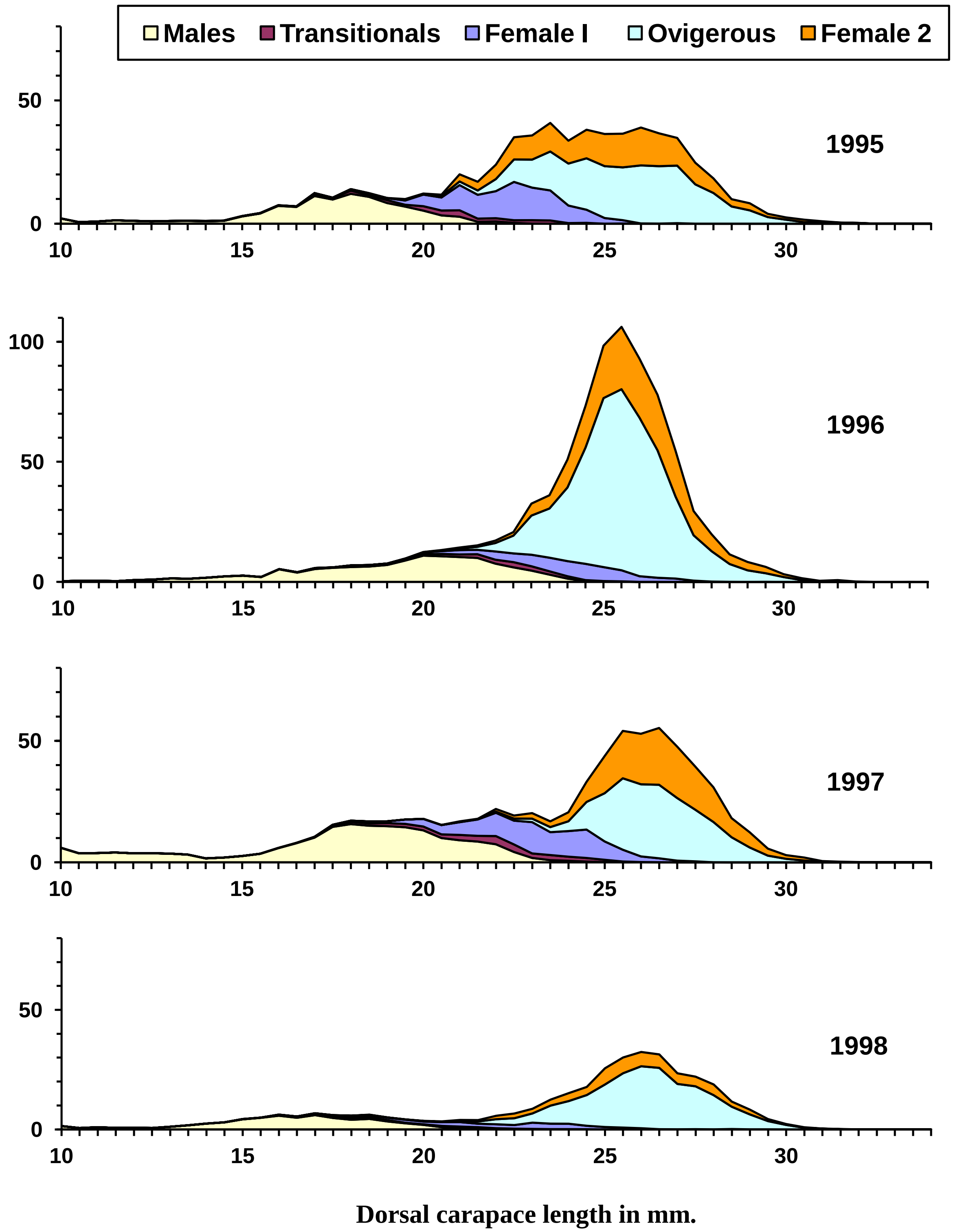


Figure 5 continued – Landings in estimated numbers of shrimp.

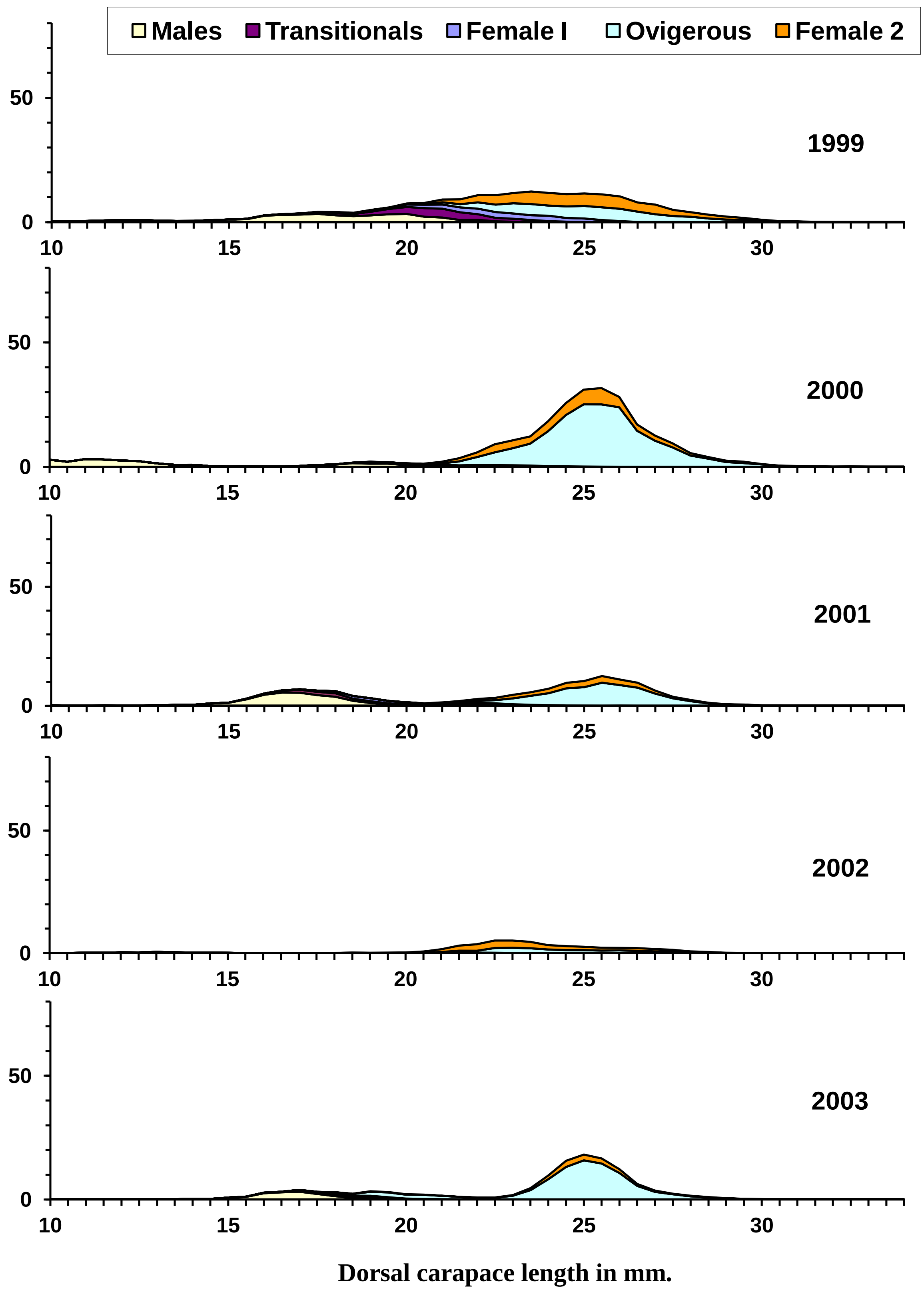


Figure 5 continued – Landings in estimated numbers of shrimp.

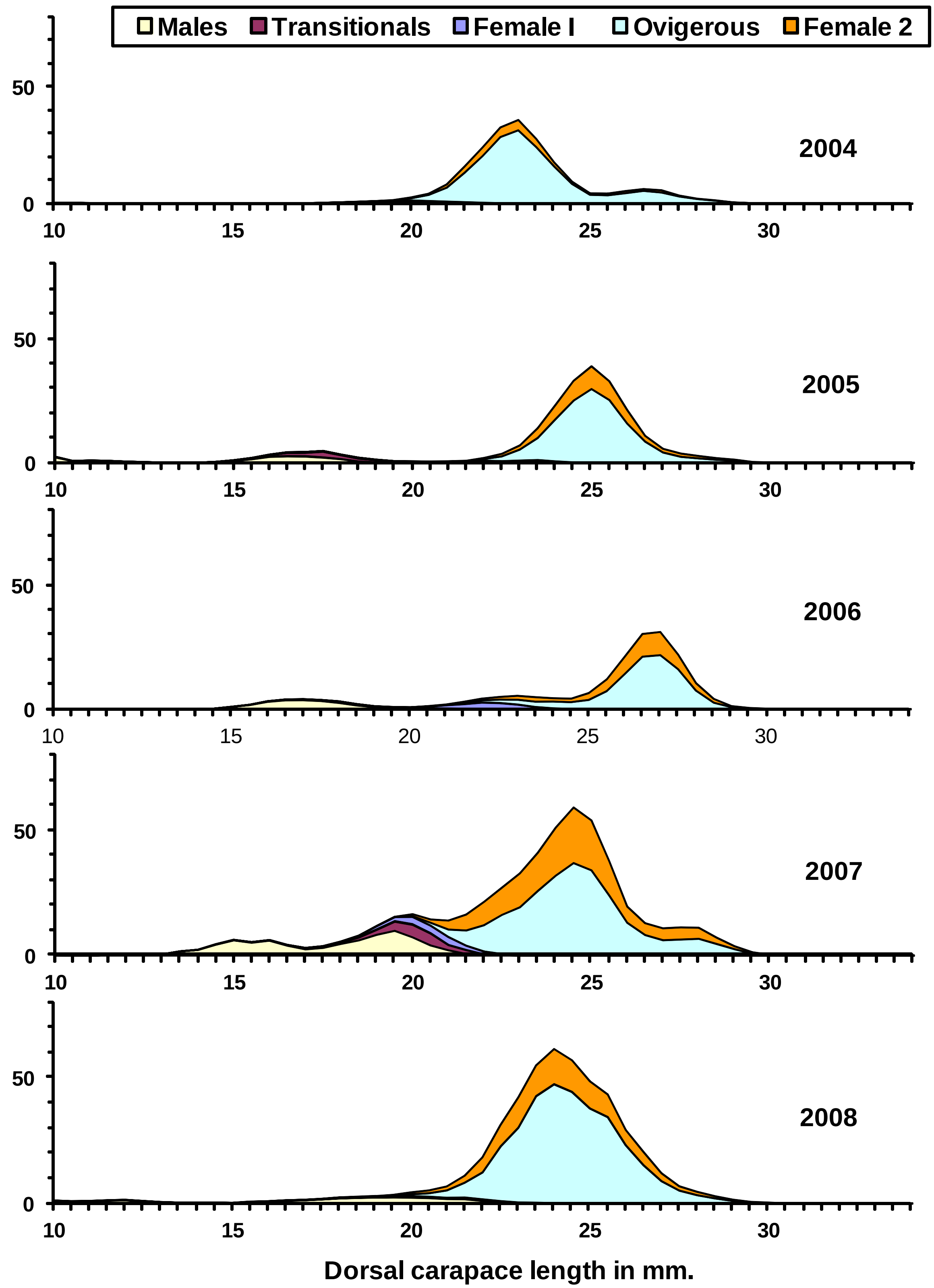


Figure 5 continued – Landings in estimated numbers of shrimp.

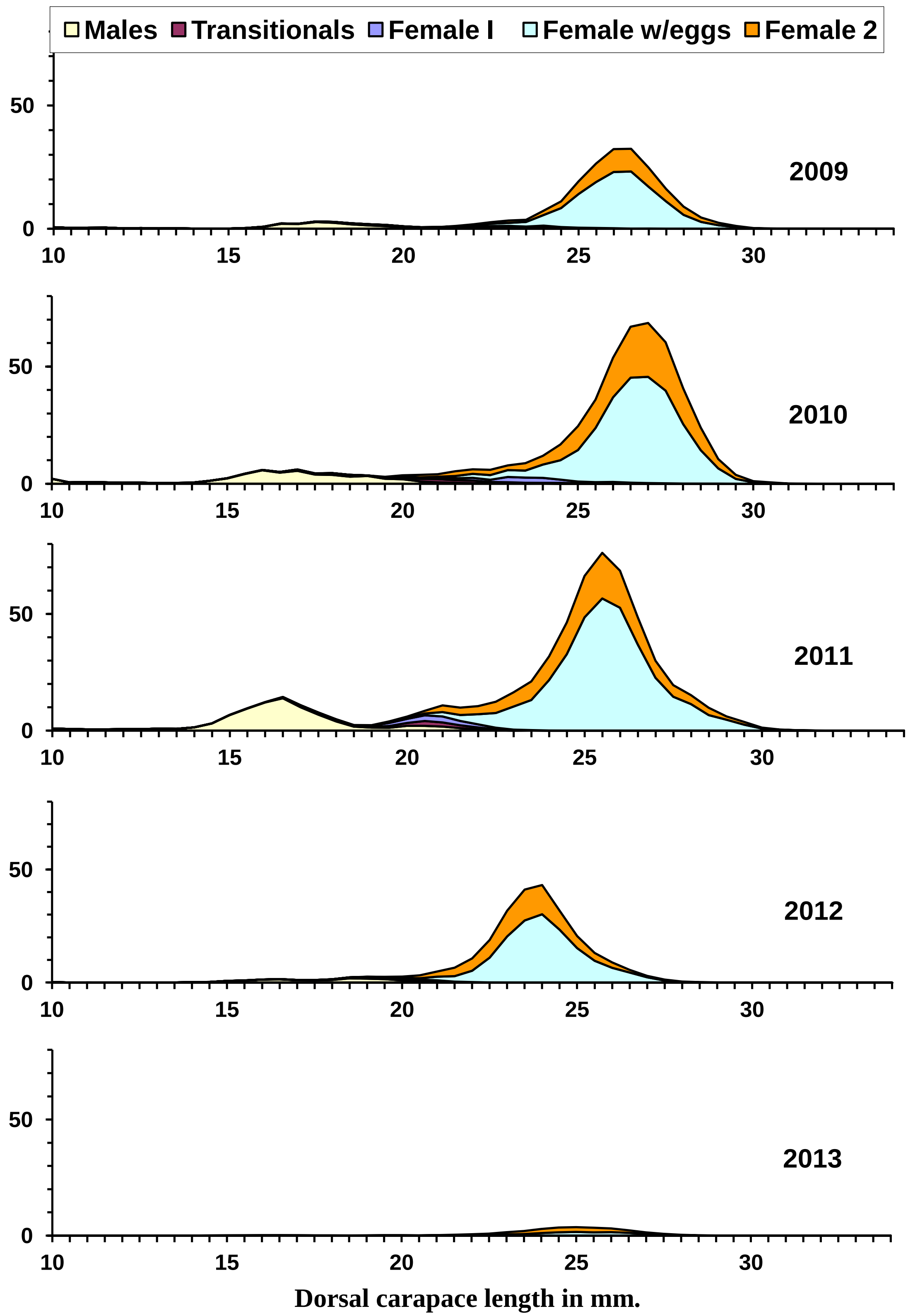


Figure 5 continued – Landings in estimated numbers of shrimp. Data for 2012 and 2013 are preliminary.

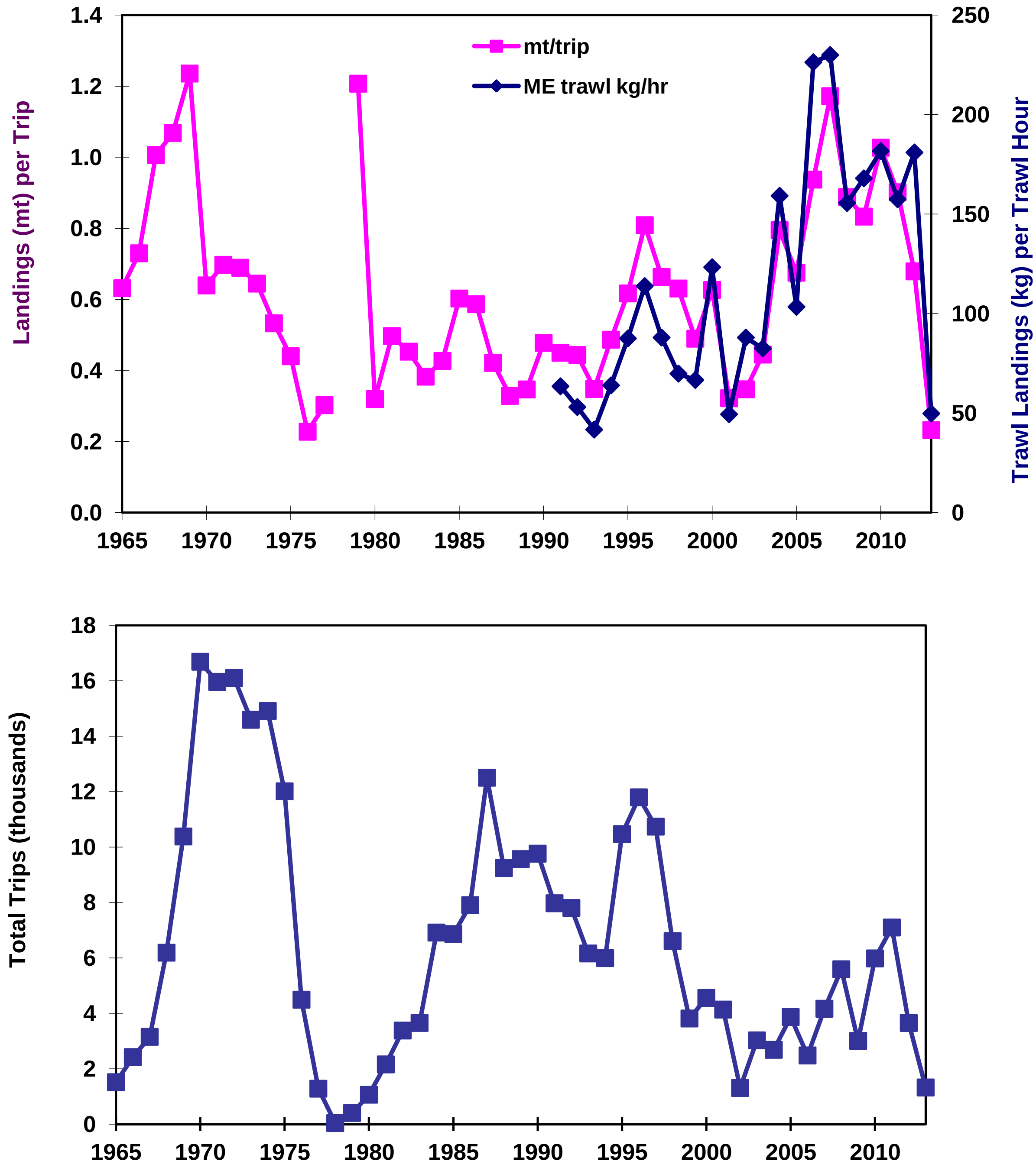


Figure 6. Catch per unit effort (above) in the Gulf of Maine northern shrimp fishery by season, and nominal fishing effort (trips) (below).2012 and 2013 trip data are preliminary.

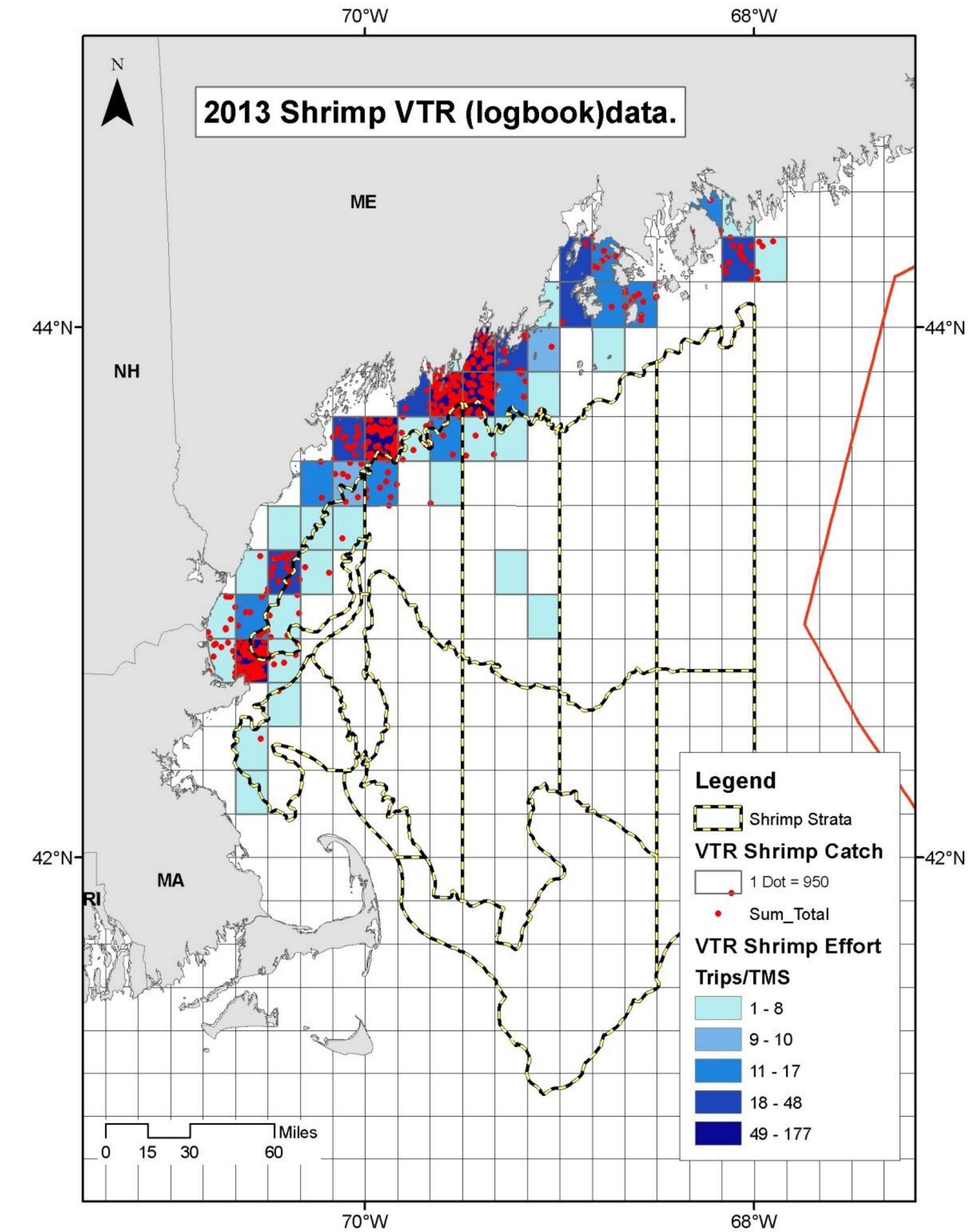


Figure 7. Pounds caught and numbers of trips during the 2013 northern shrimp fishing season by 10-minute-square. Each red dot represents 950 lbs caught; locations of dots within squares are random and do not reflect the actual location of the catch. Number of trips is indicated by the blue palette for the squares. From preliminary state and federal harvester logbook (VTR) data.

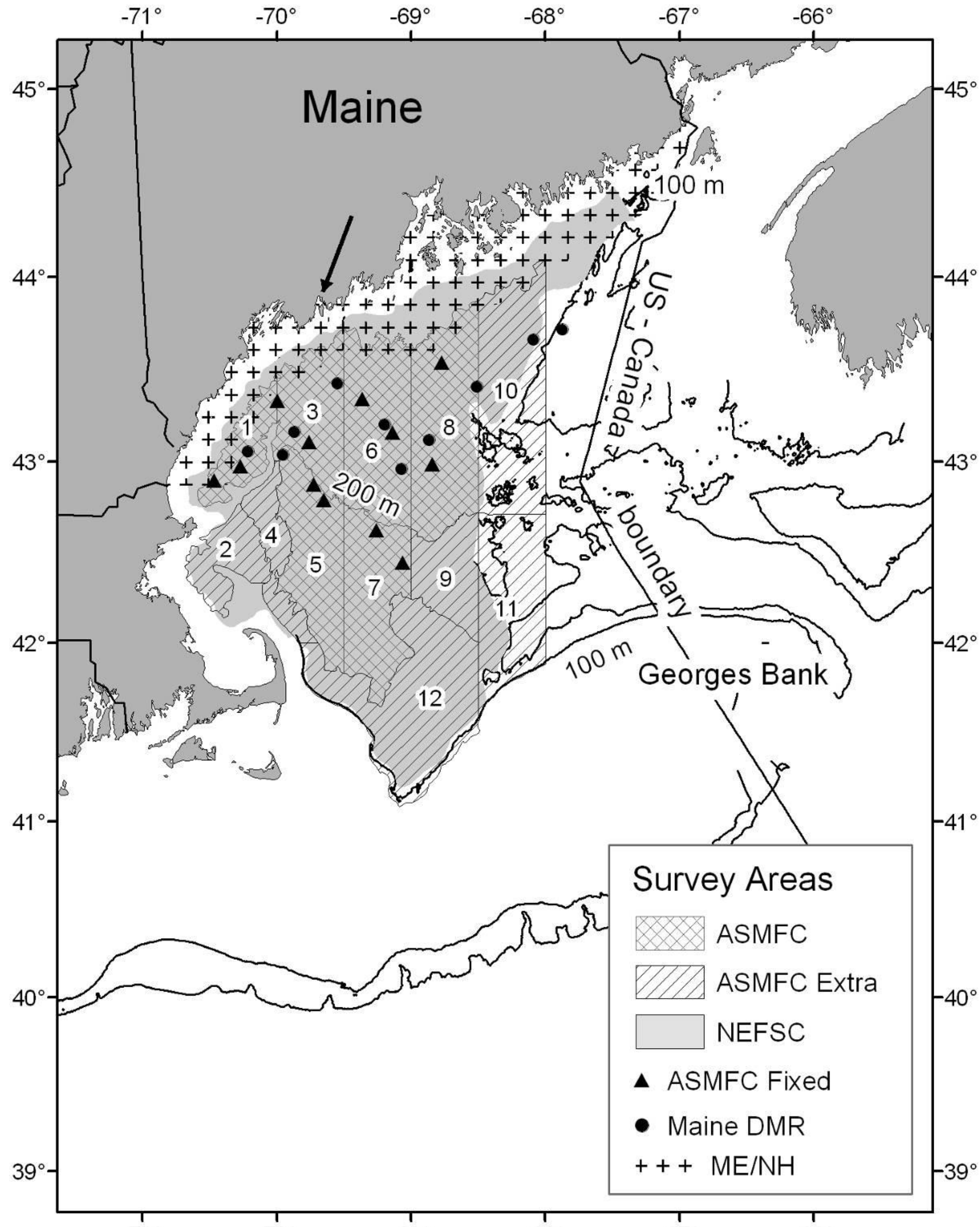
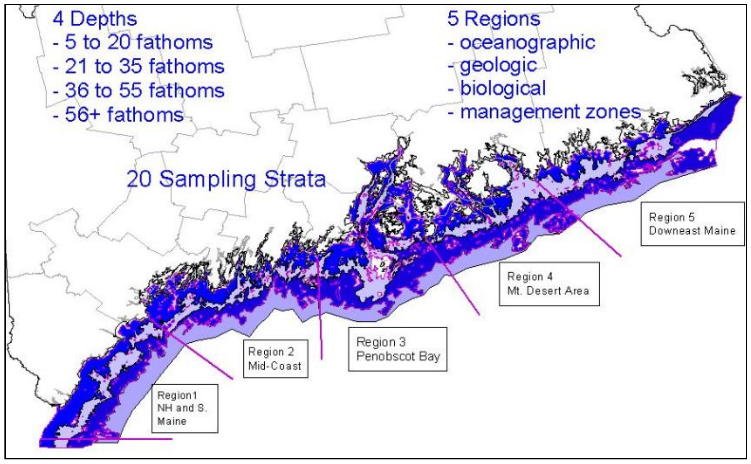


Figure 8a. Gulf of Maine survey areas and station locations. The arrow indicates the location of Boothbay Harbor, Maine, referenced in Figure 20.



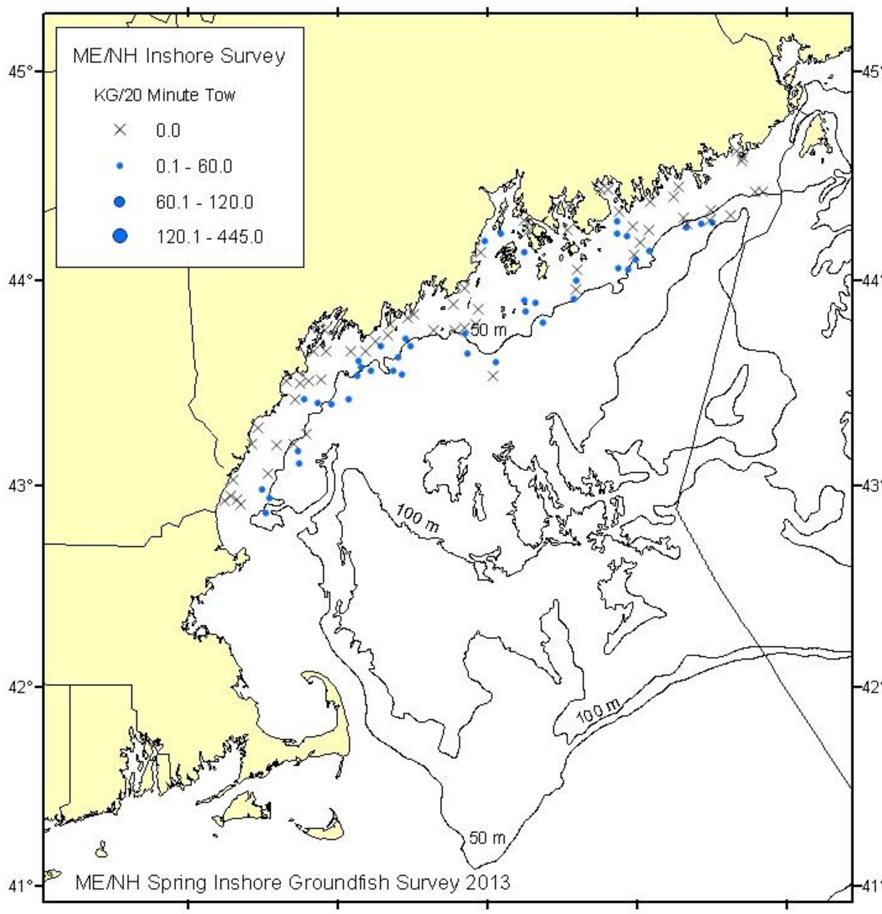


Figure 8b. Maine-New Hampshire inshore trawl survey depths and regions (above) and spring 2013 results for northern shrimp (below).

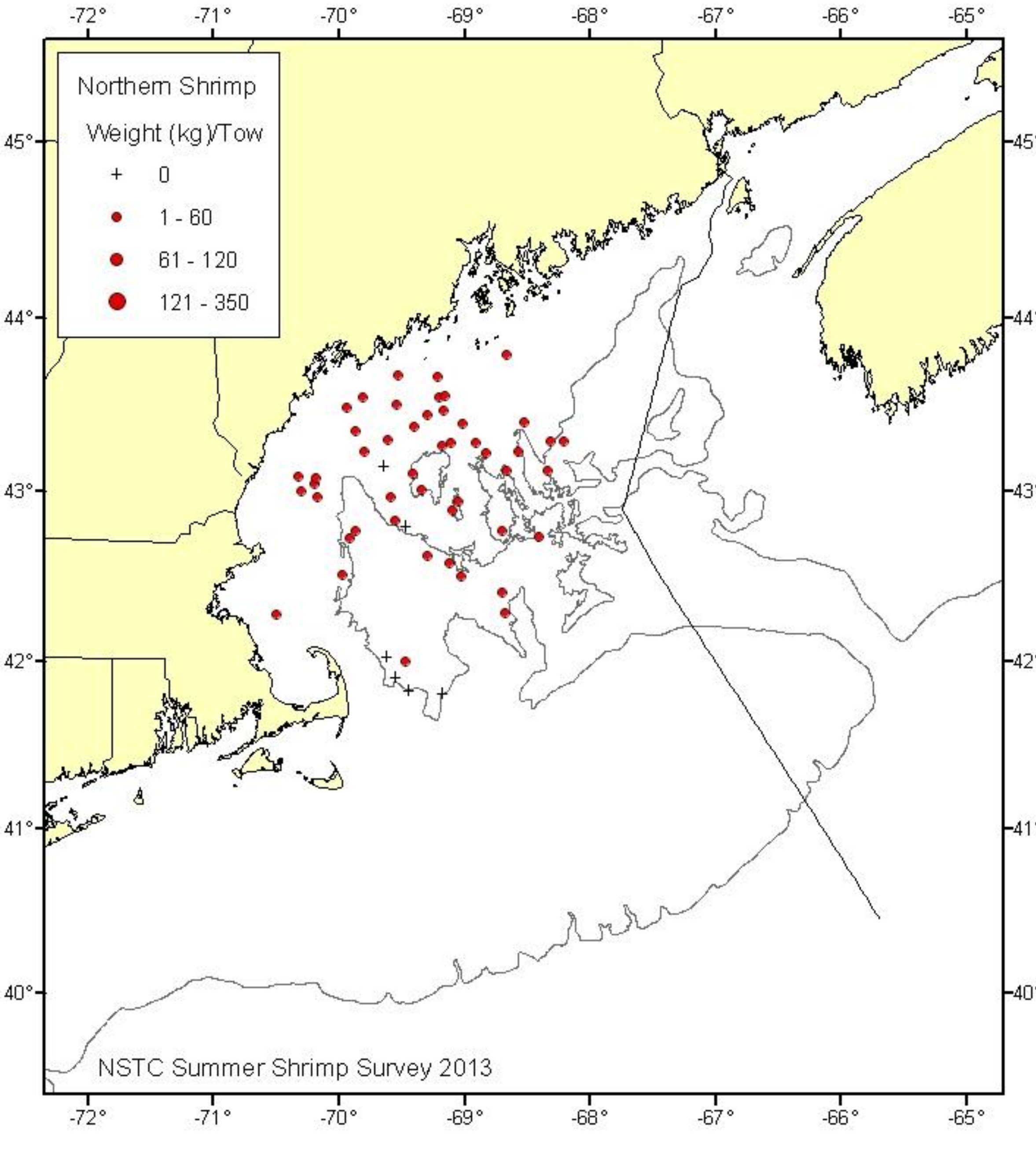


Figure 8c. State/federal summer northern shrimp survey aboard the *R/V Gloria Michelle*, July 22 – August 14, 2013, random survey sites and shrimp catches in kg/tow.

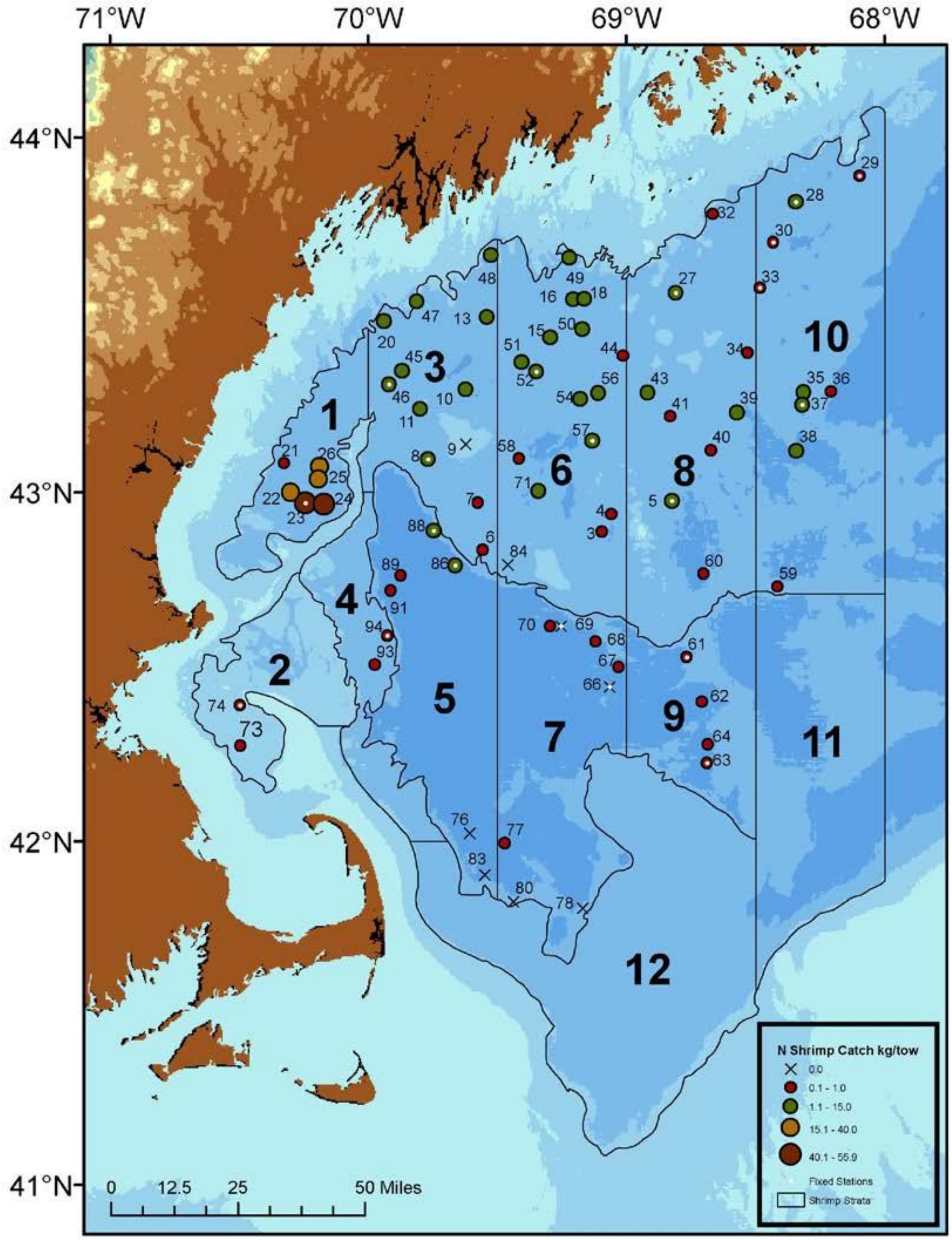


Figure 8d. State/federal summer northern shrimp survey aboard the *R/V Gloria Michelle*, July 22 – August 14, 2013, fixed and random survey sites and shrimp catches in kg/tow.

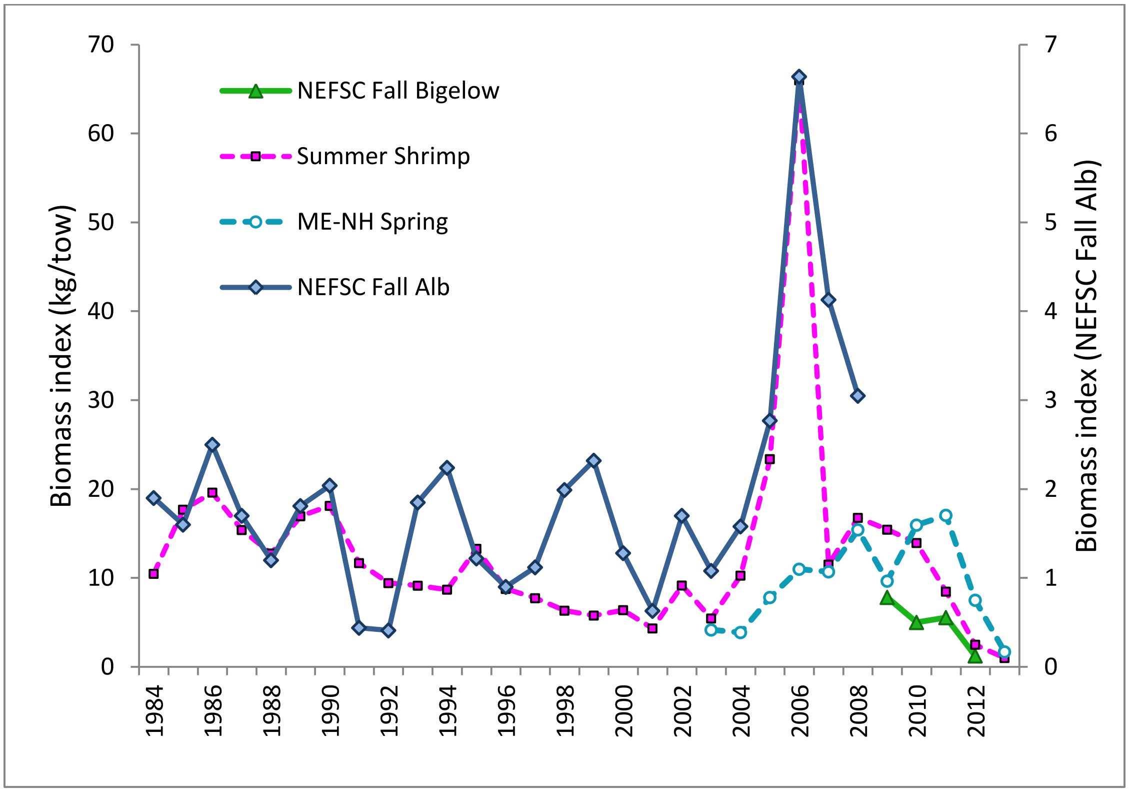


Figure 9. Biomass indices (kg/tow) from various northern shrimp surveys in the Gulf of Maine.

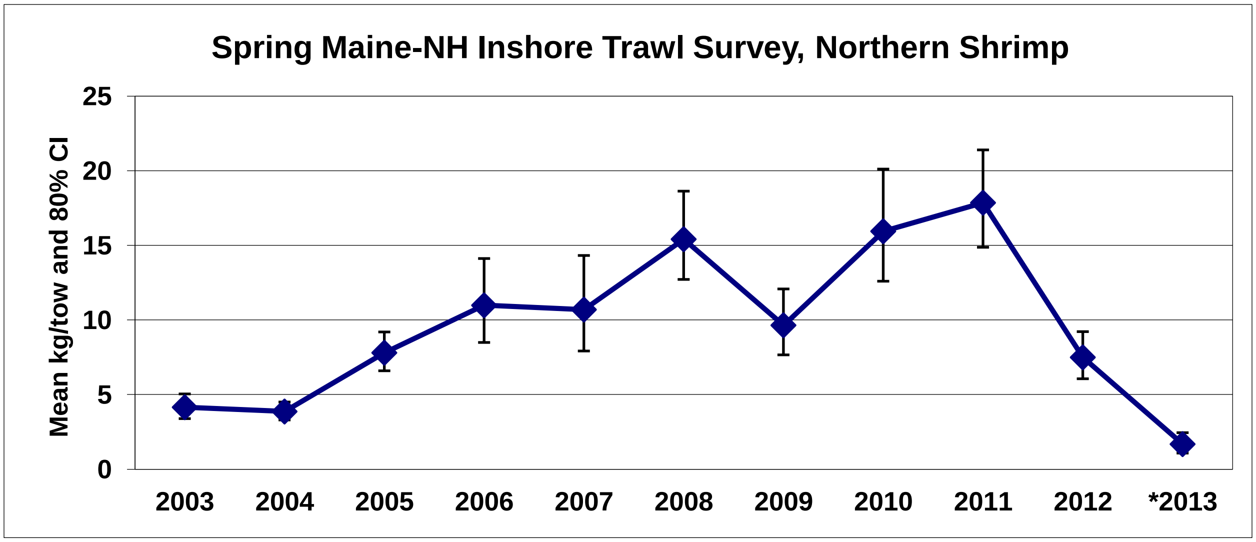


Figure 10a. Spring Maine-New Hampshire inshore trawl survey biomass indices for northern shrimp, with 80% confidence intervals. *2013 data are preliminary.

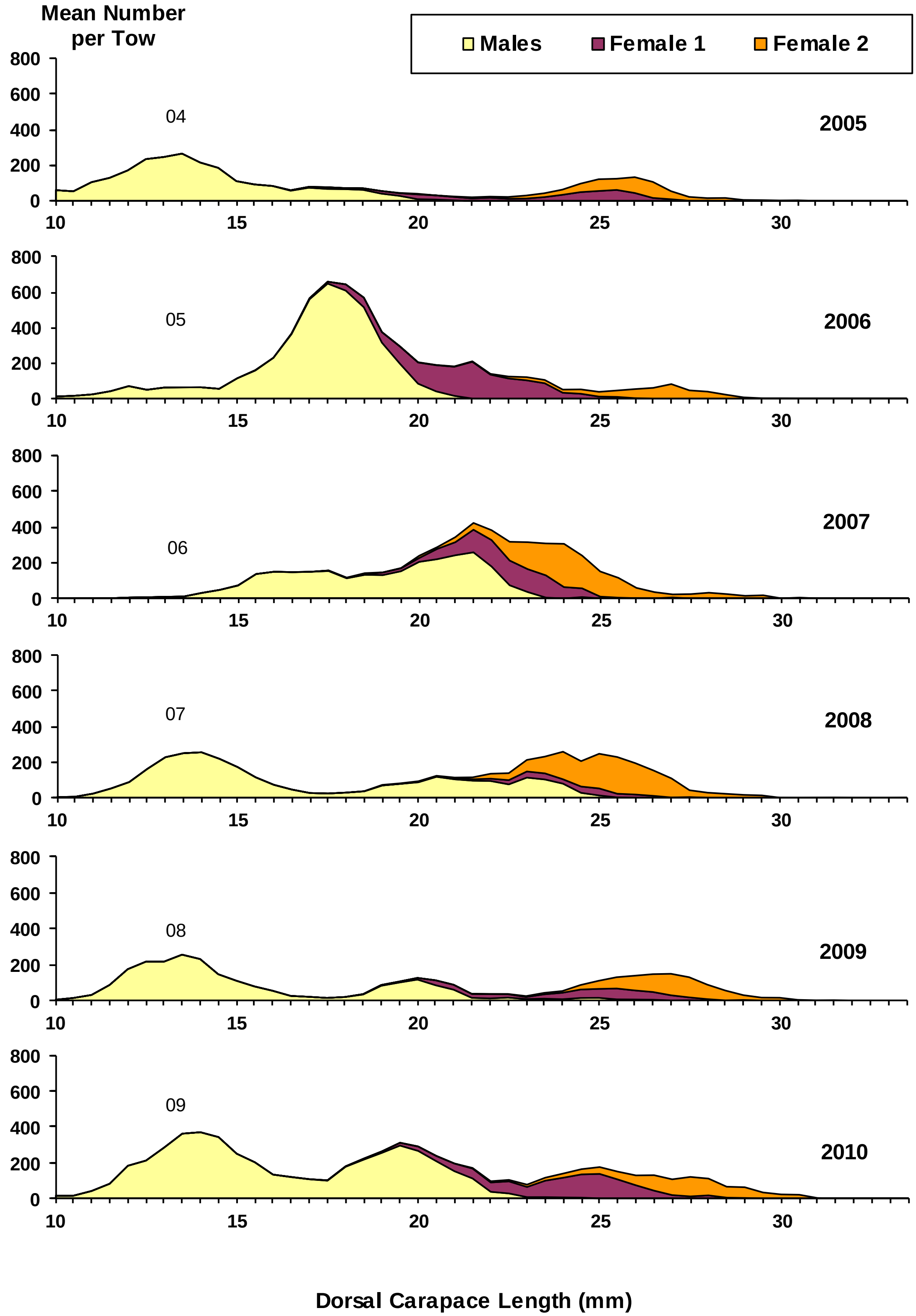


Figure 10b. **Maine-New Hampshire spring inshore survey; northern shrimp untransformed mean catch per tow by year, length, and development stage. Two-digit years are the year class at assumed age 1.**

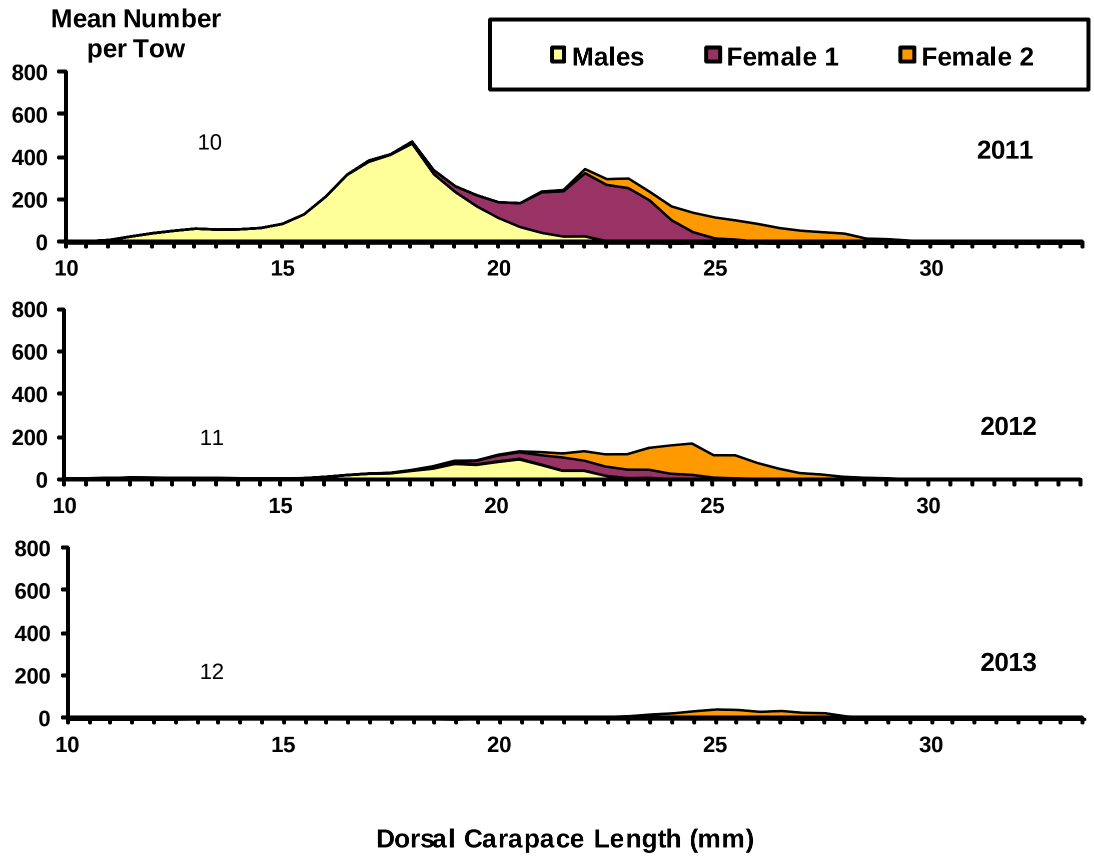
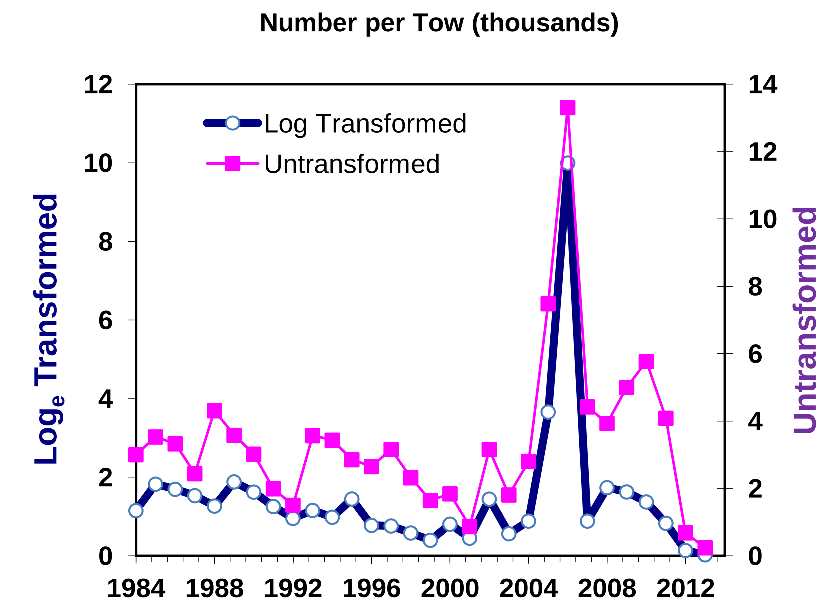


Figure 10b continued - ME/NH spring inshore survey.



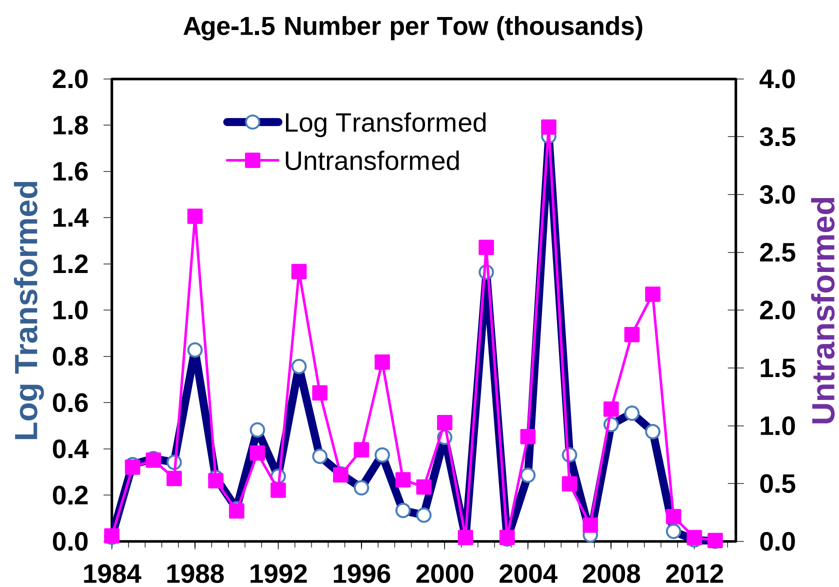
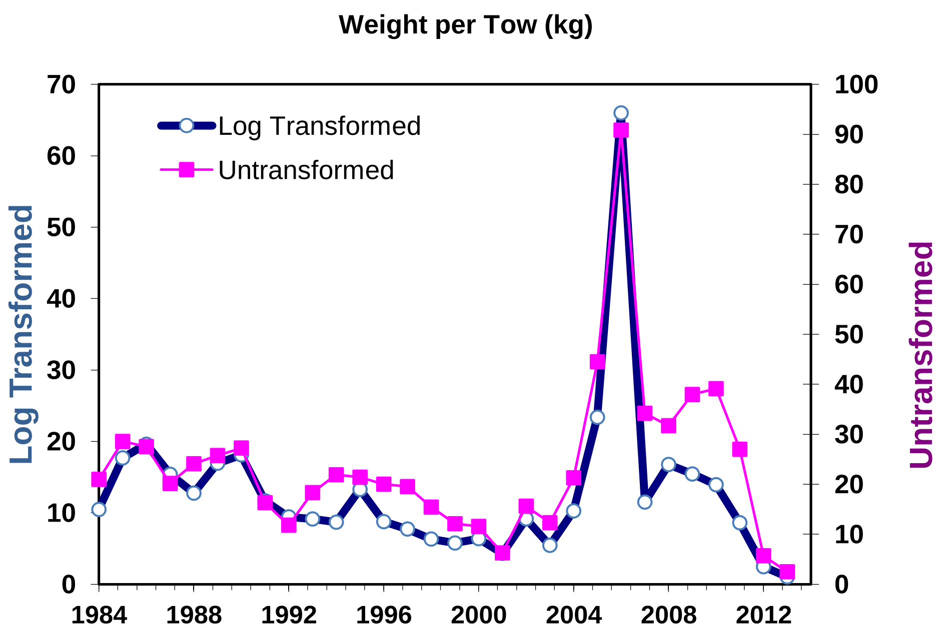


Figure 11a. Gulf of Maine northern shrimp summer survey indices of abundance by survey year.



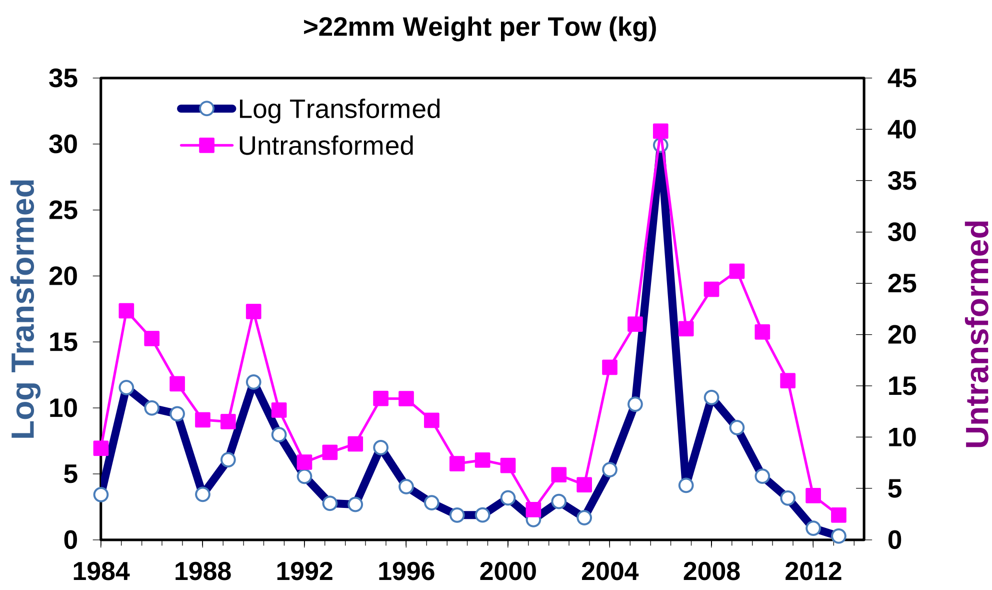


Figure 11b. Gulf of Maine northern shrimp survey indices of biomass by survey year.

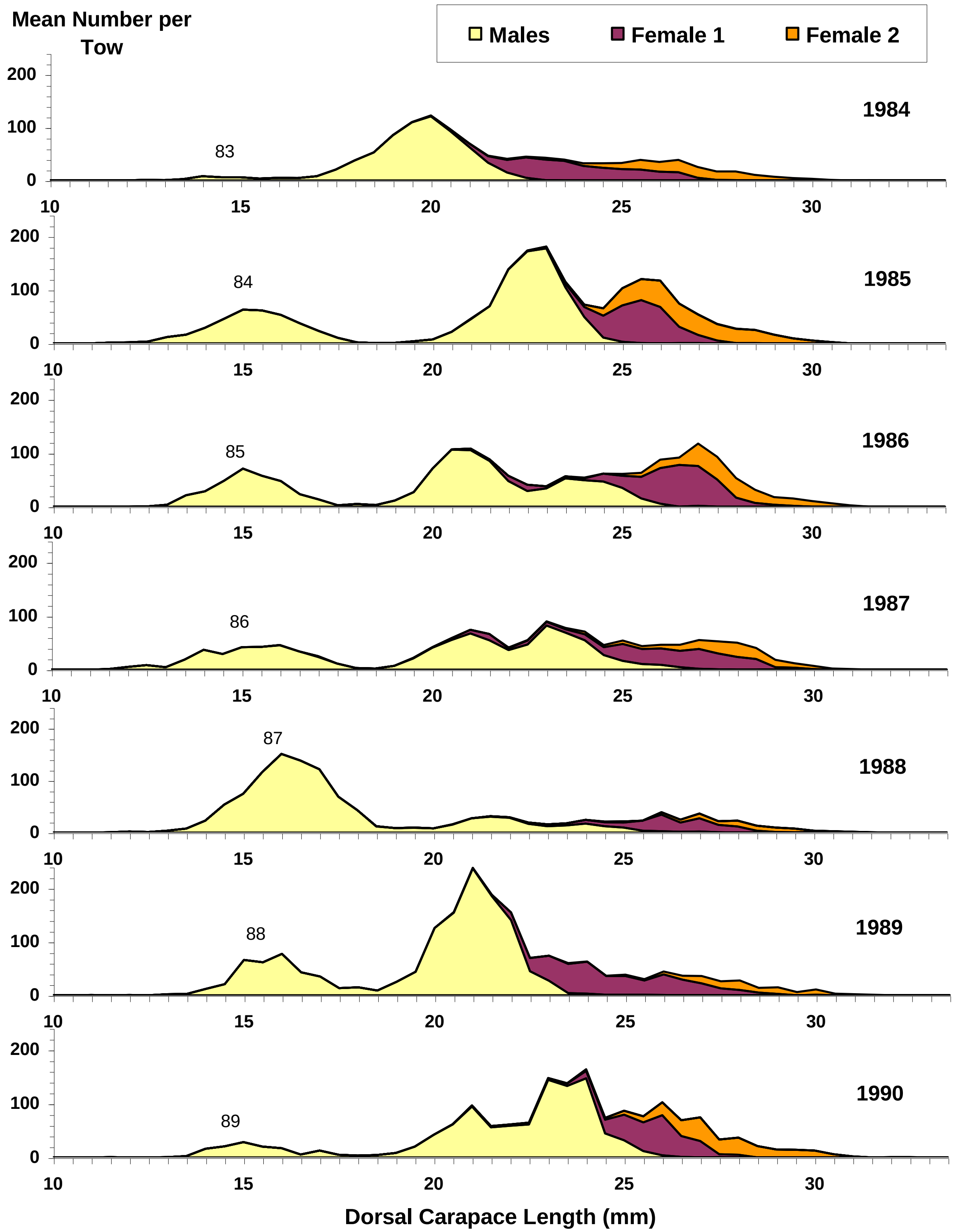


Figure 12. **Gulf of Maine northern shrimp summer survey mean catch per tow by year, length, and development stage. Two-digit years are year class at assumed age 1.5.**

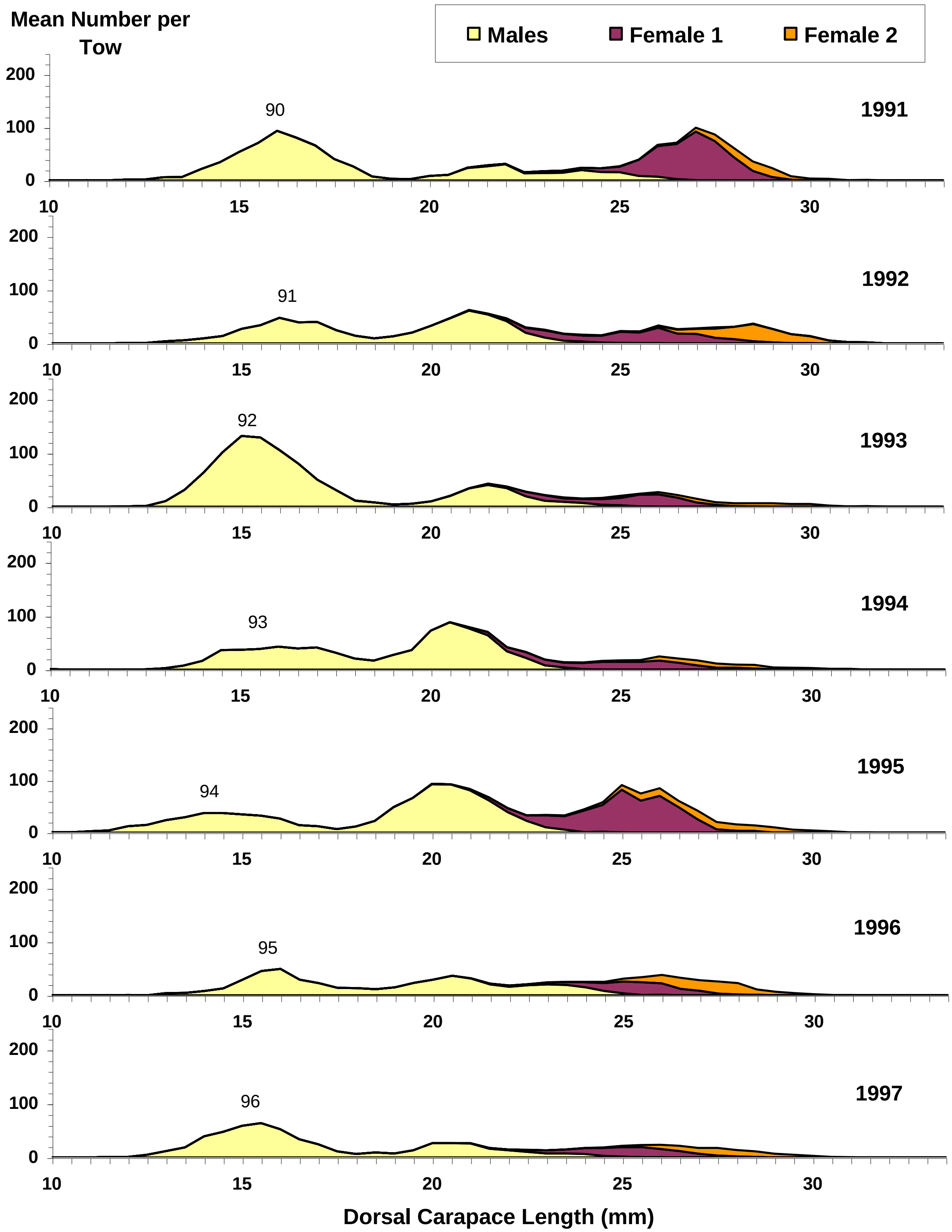


Figure 12 continued – summer survey.

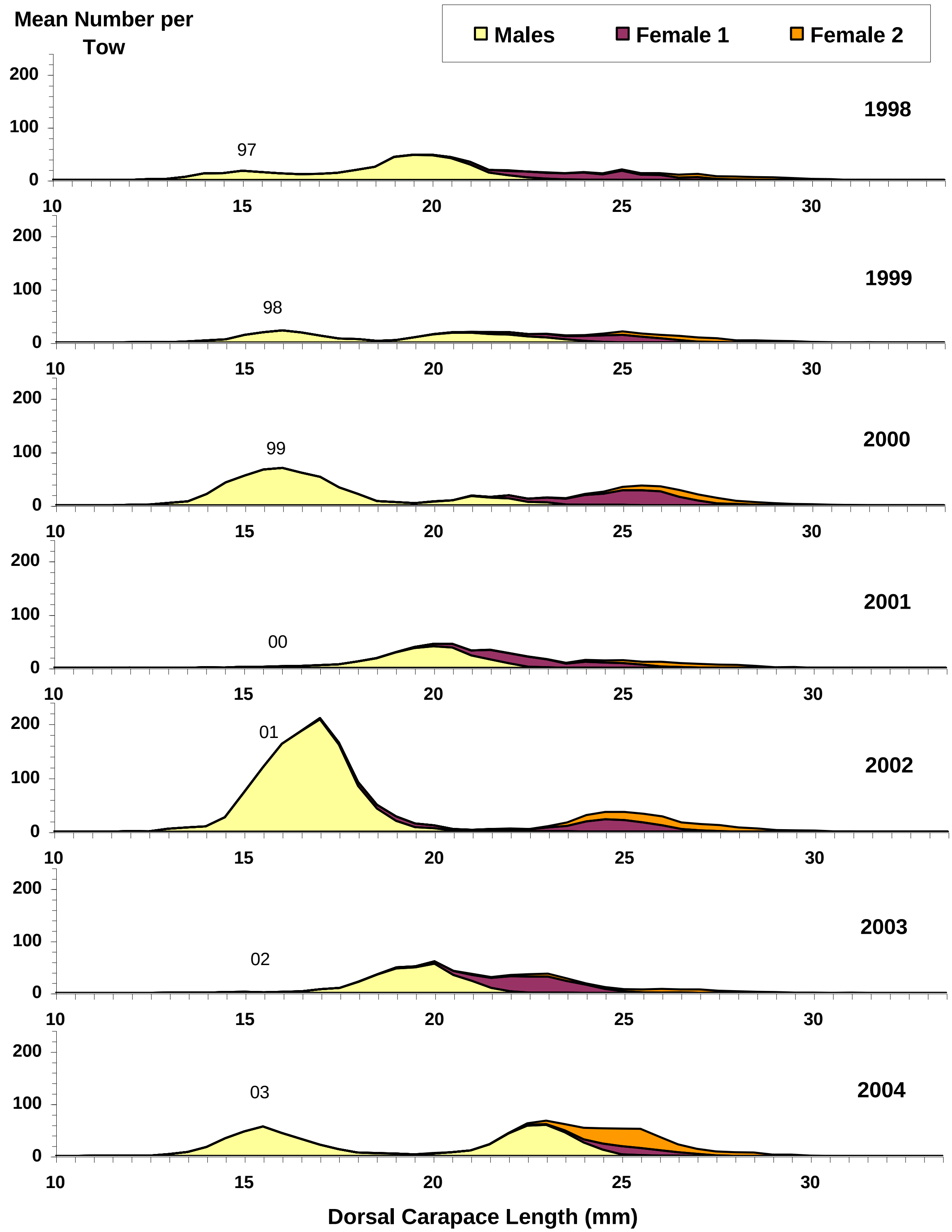


Figure 12 continued – summer survey.

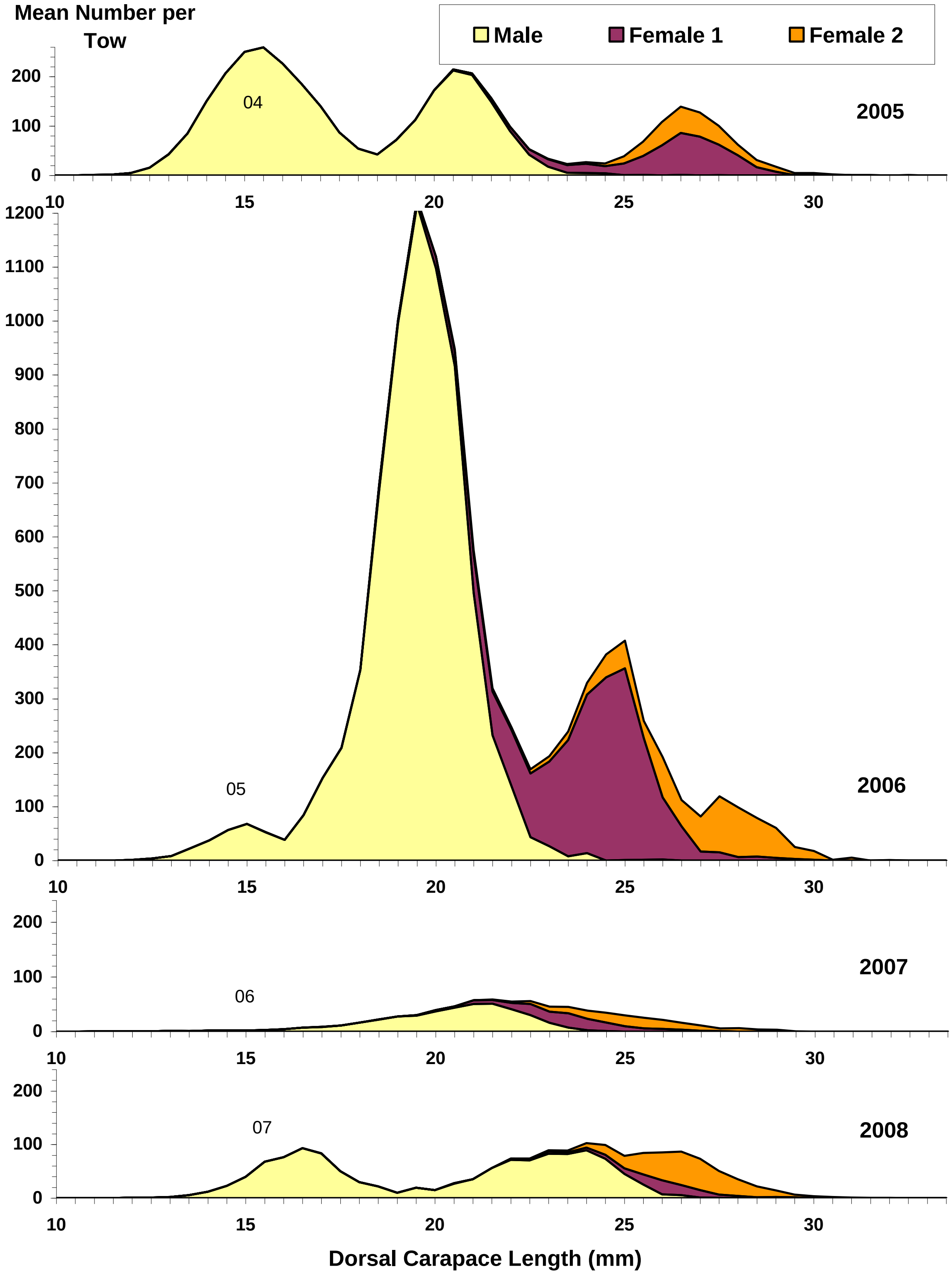


Figure 12 continued – summer survey.

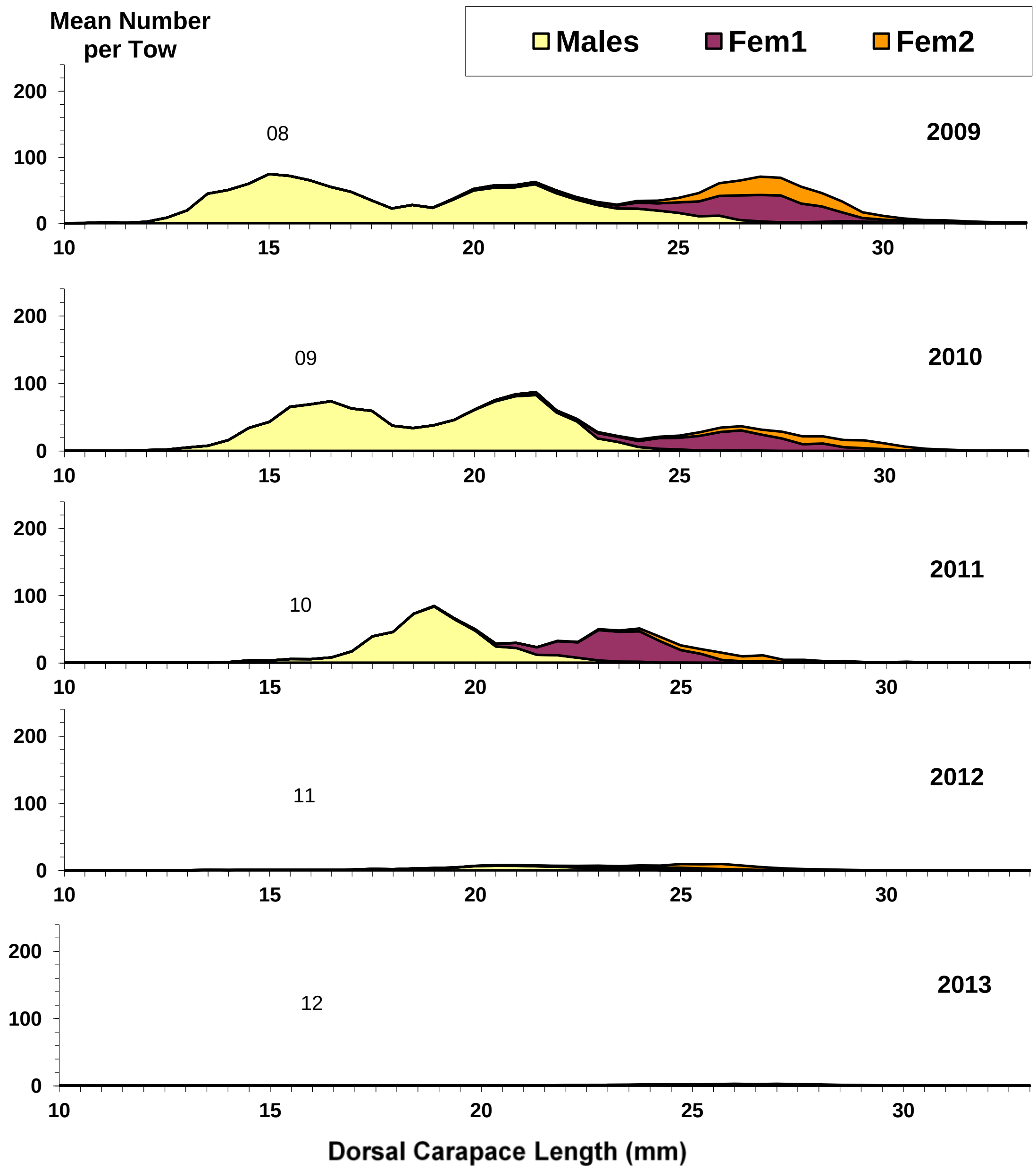


Figure 12 continued – summer survey.

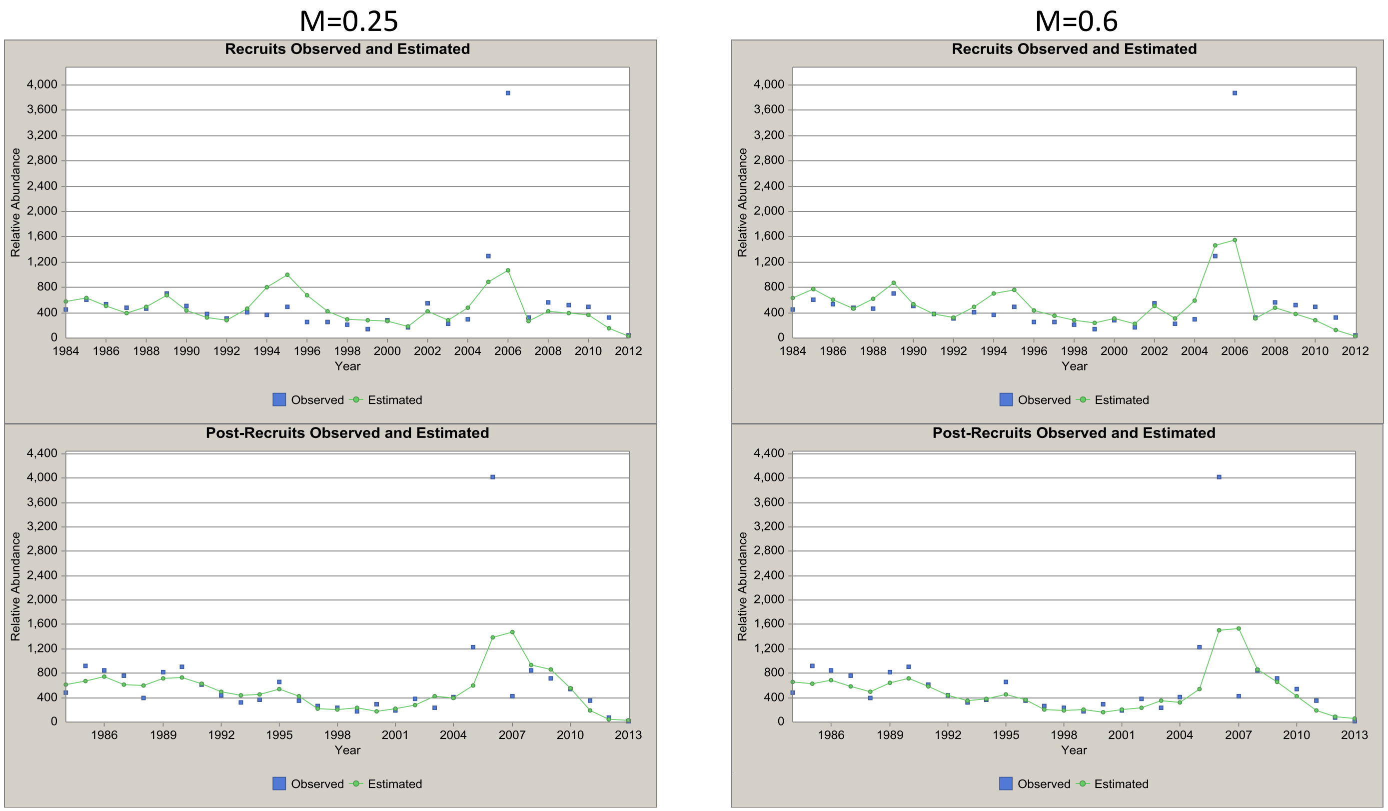


Figure 13a. Model estimates of relative abundance compared to observed abundance indices for recruits and post-recruits. (A) from CSA assuming M=0.25 (left), (B) from CSA assuming M=0.6.

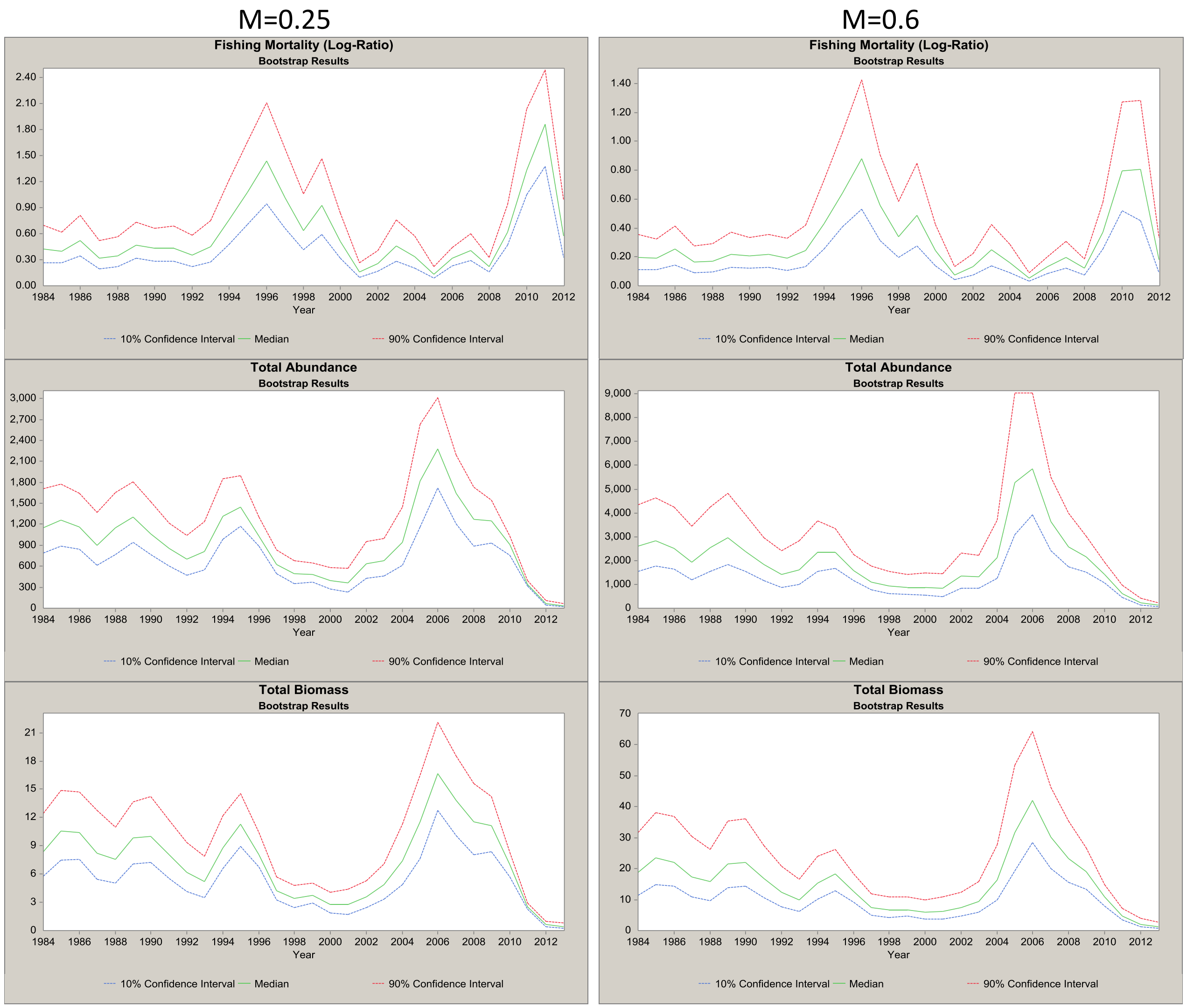


Figure 13b. Fishing mortality, exploitable abundance, and exploitable biomass of Gulf of Maine northern shrimp estimated by CSA assuming M=0.25 (left column) and M=0.60 (right column), least squares estimates (line), bootstrapped medians (squares) with 80% confidence intervals.

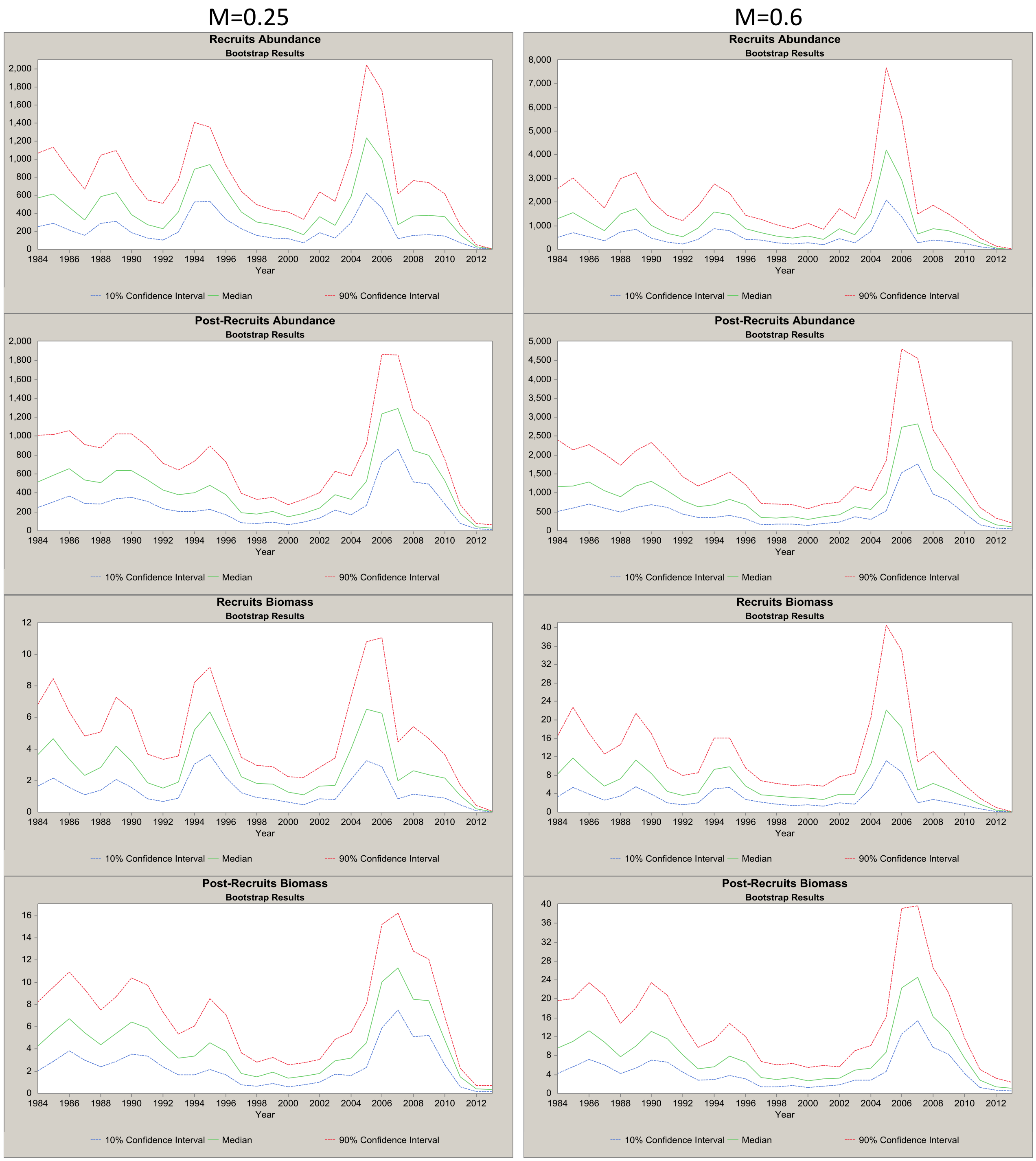


Figure 13b, continued – CSA results.

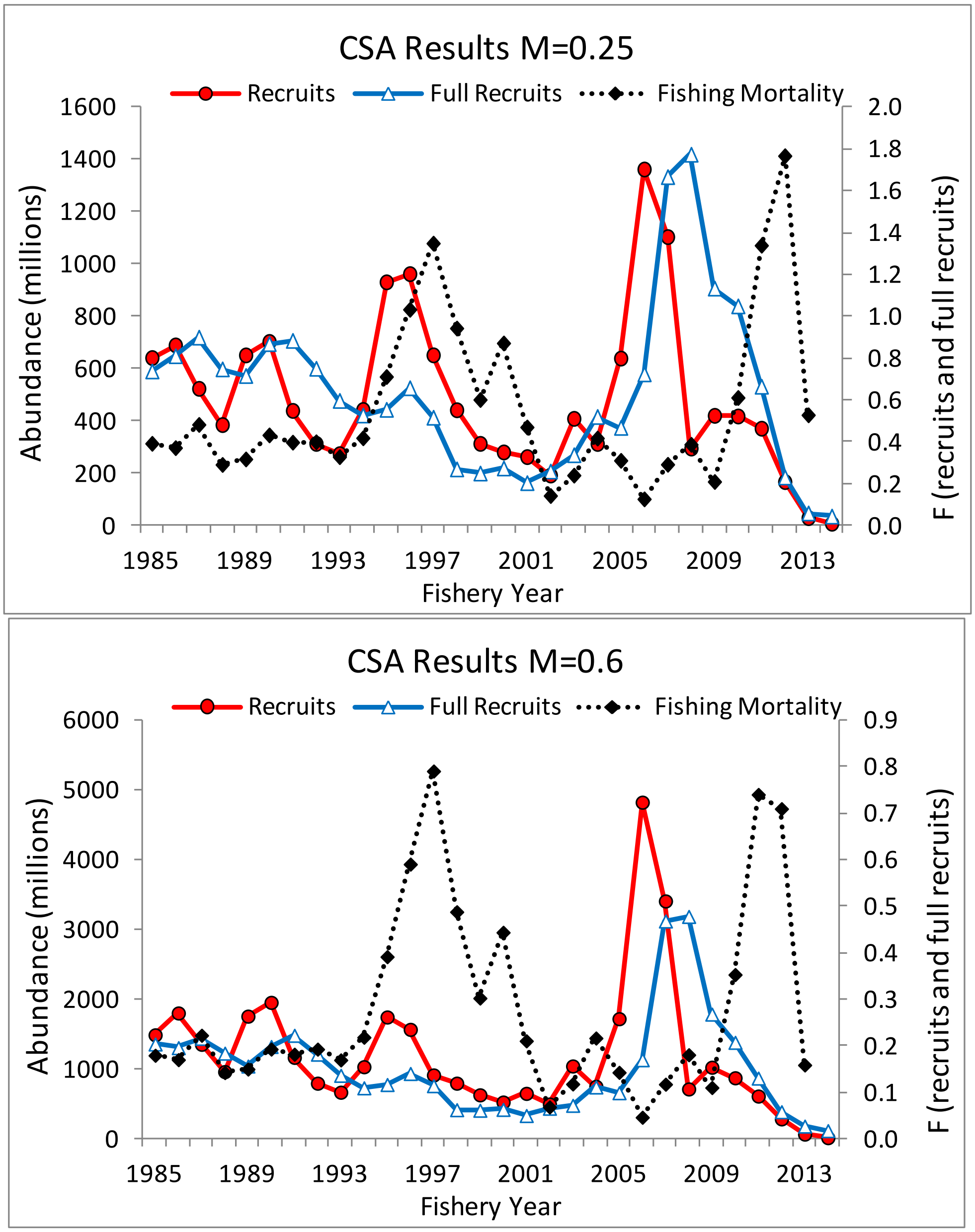


Figure 14a. CSA estimates of abundance and fishing mortality assuming M=0.25 and M=0.60.

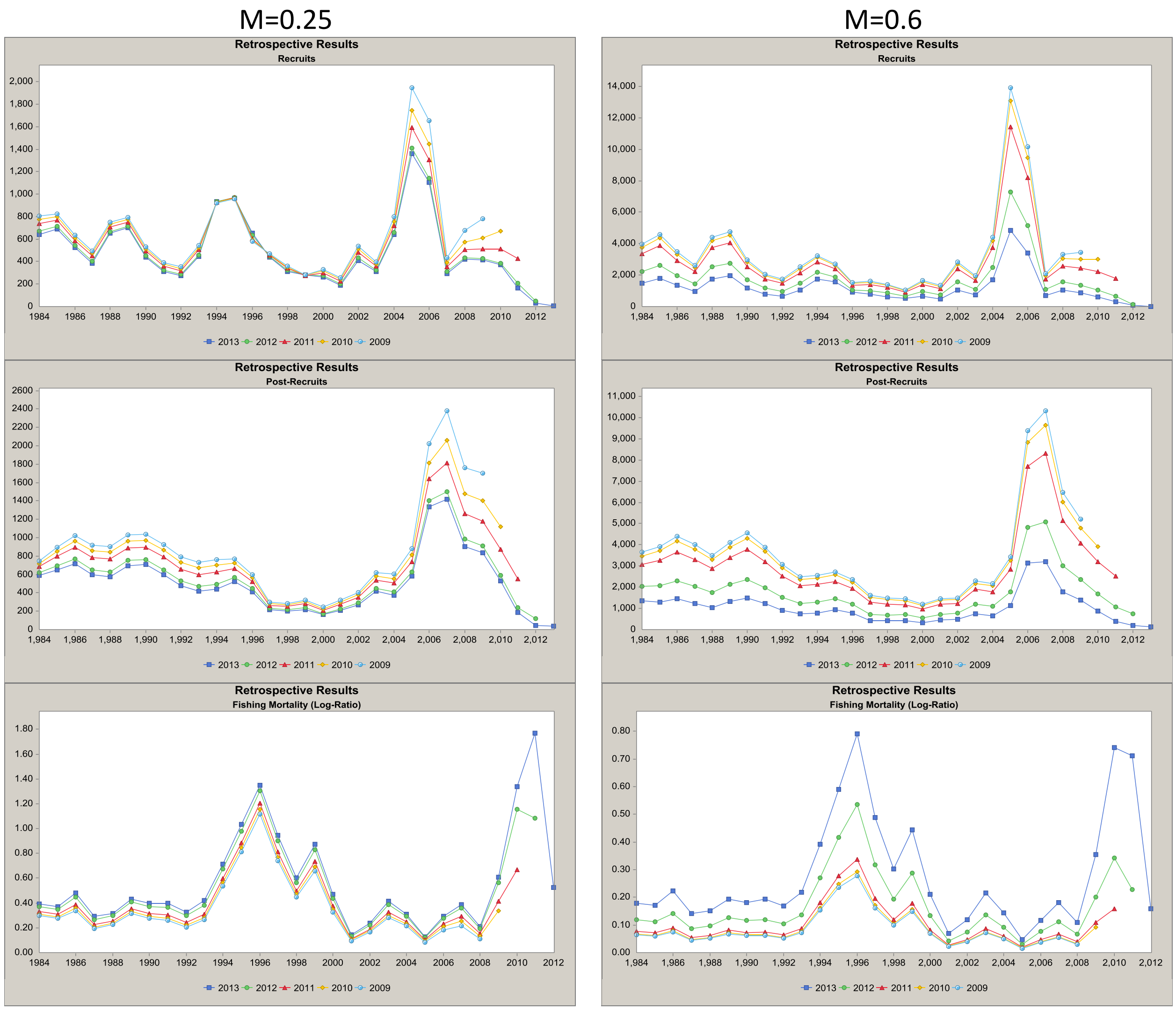
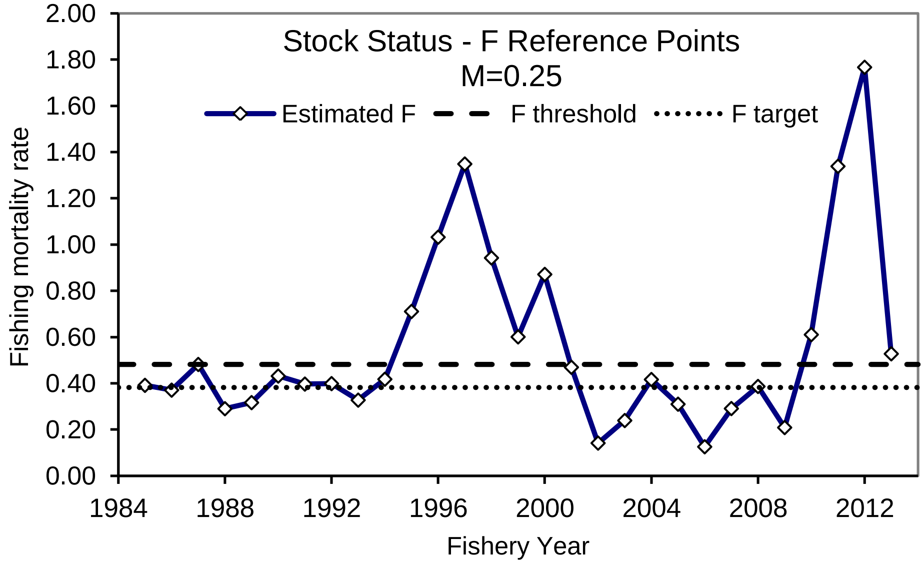


Figure 14b. Retrospective analysis of CSA results for M=0.25 and M=0.60. Models were run starting with a terminal year of 2009 and successively adding years to show how model estimates change as more information is added.



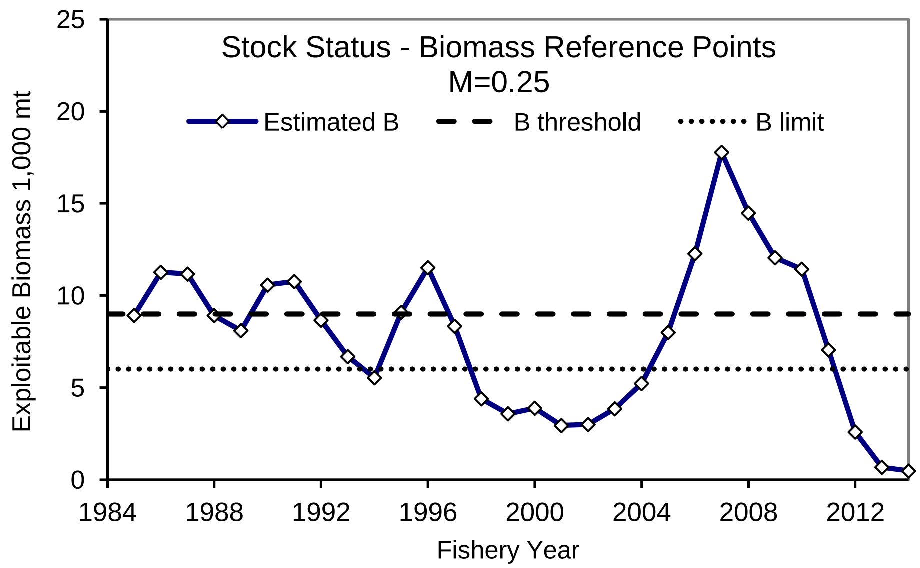


Figure 15. Estimated fishing mortality and biomass of Gulf of Maine northern shrimp (CSA, M=0.25) relative to biological reference points.

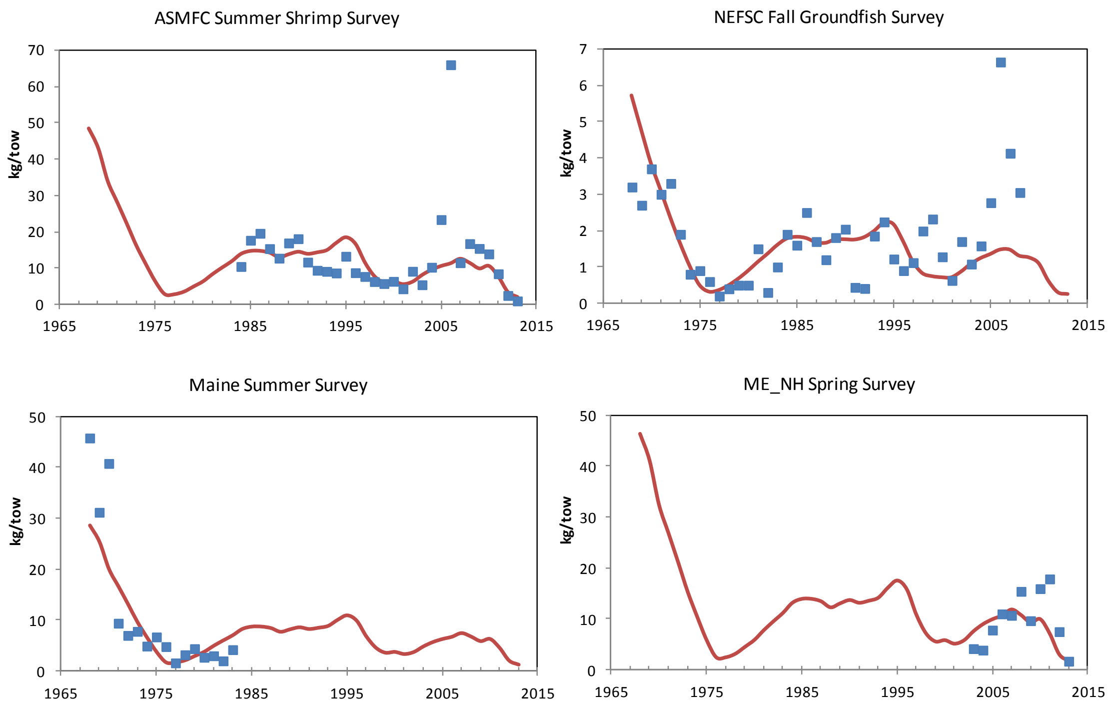


Figure 16a. Observed and predicted index values (top) and residuals (bottom) for survey biomass indices from surplus production model (ASPIC).

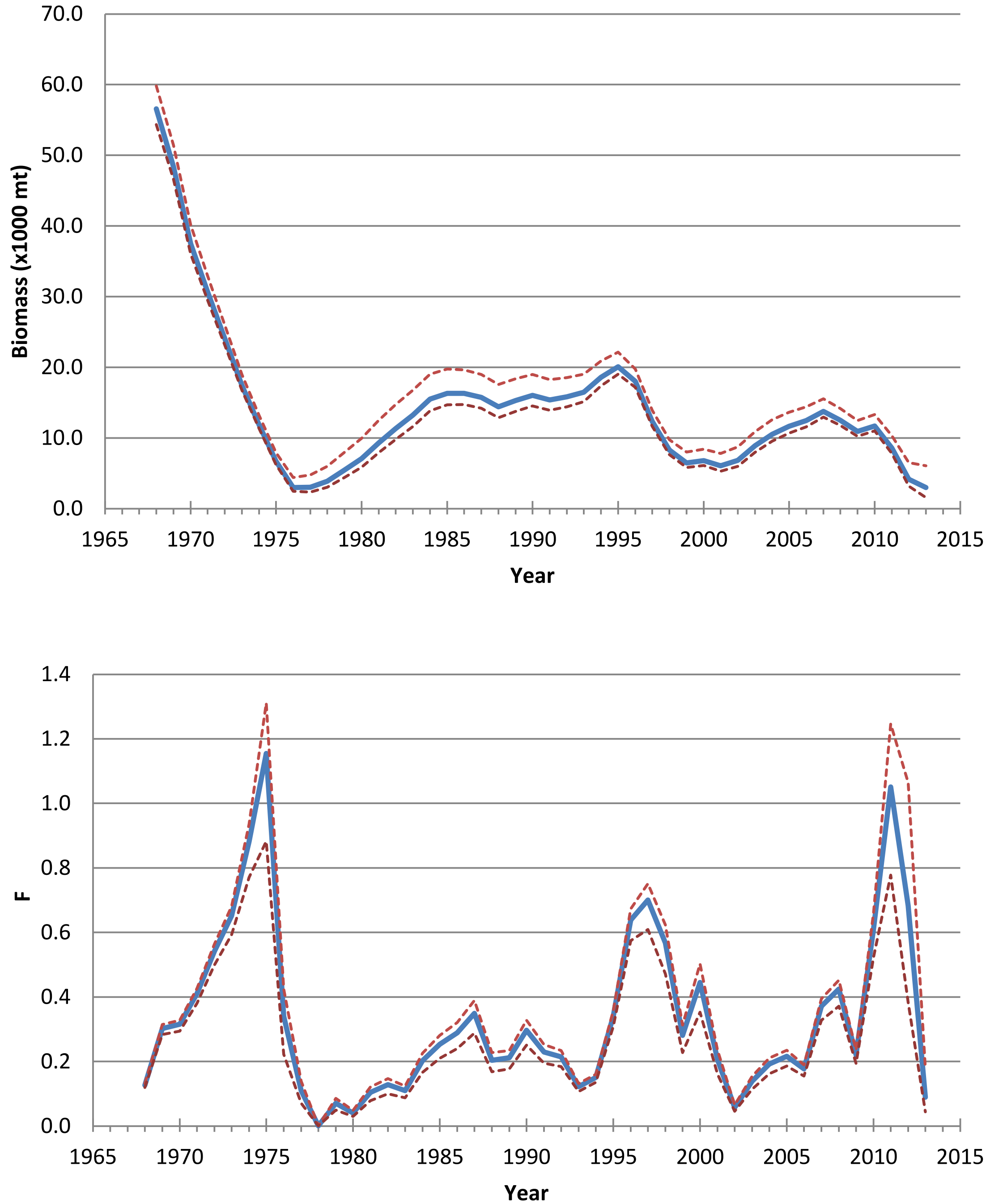
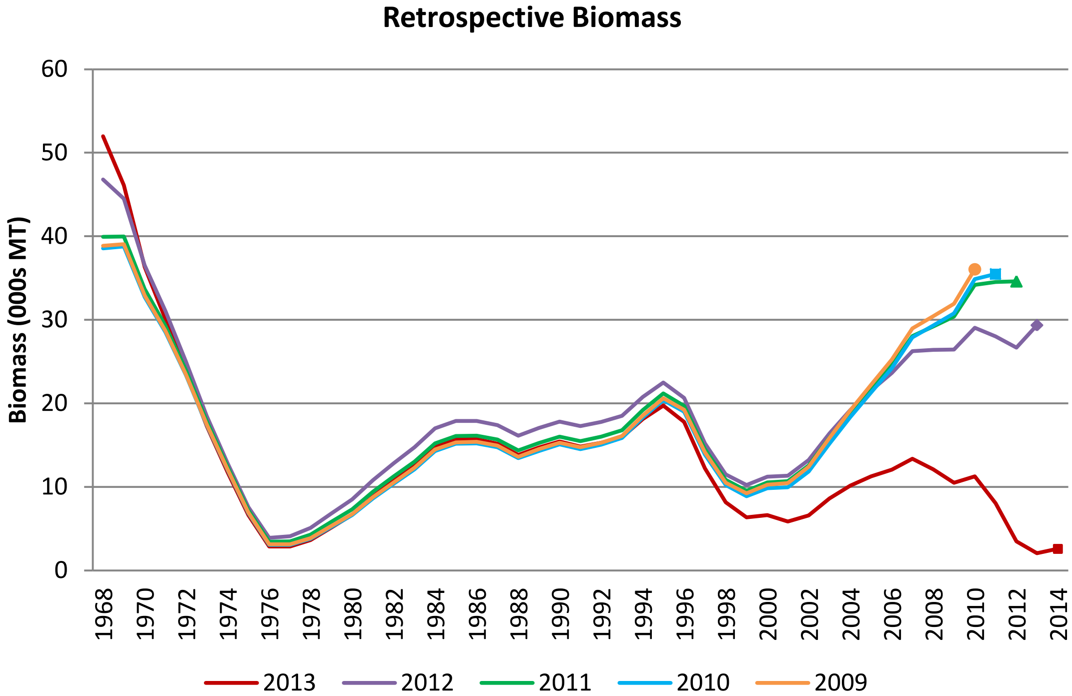


Figure 16b. Biomass (top) and fishing mortality (bottom) estimates from surplus production model (ASPIC). Dotted lines indicate bootstrapped confidence intervals (5% and 95%, blue line indicates median).



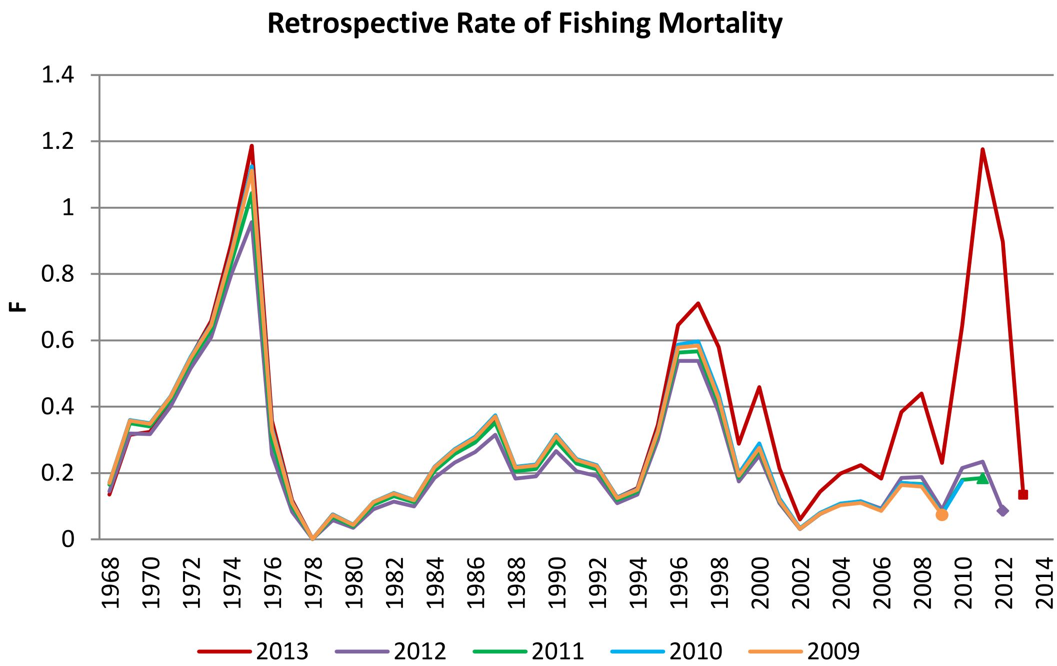


Figure 16c. Retrospective analysis of surplus production model (ASPIC) results. Models were run starting with a terminal year of 2009 and successively adding years to show how model estimates change as more information is added.

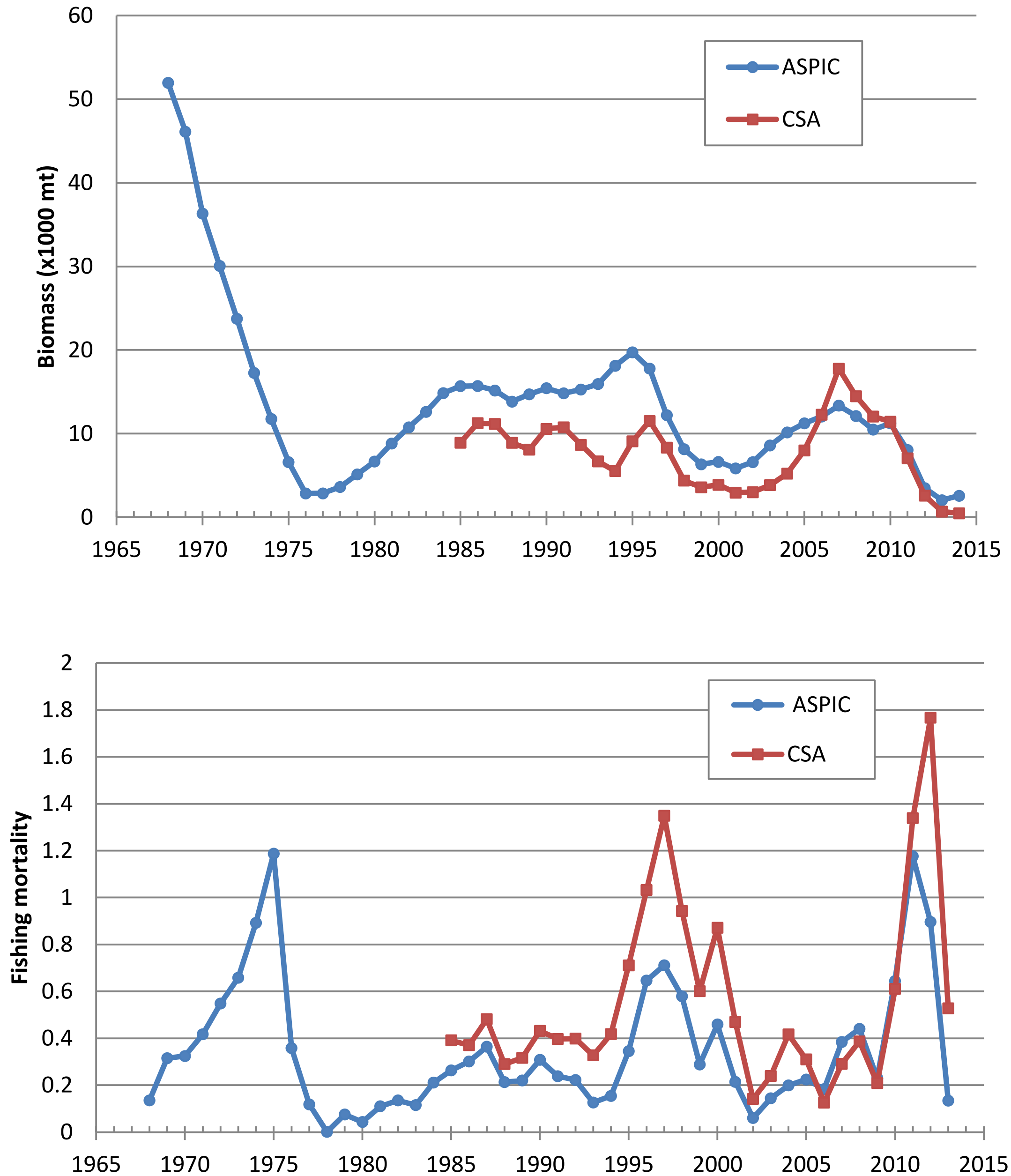
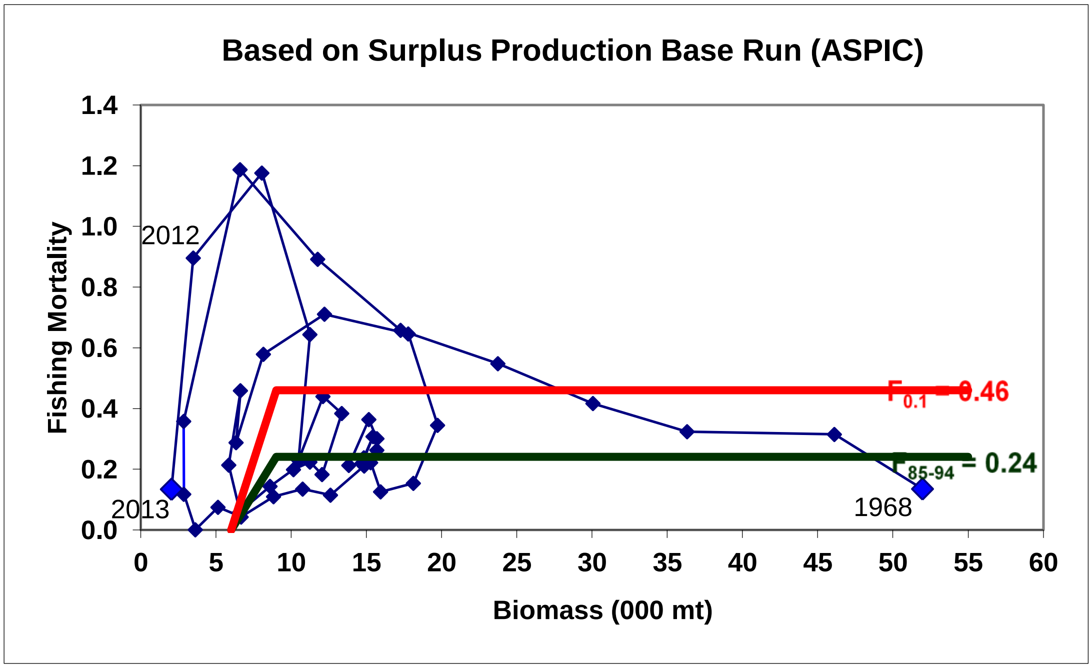


Figure 16d. Comparison of estimates of exploitable biomass (top) and fishing mortality (bottom) from surplus production (ASPIC) and CSA modeling (M=0.25).



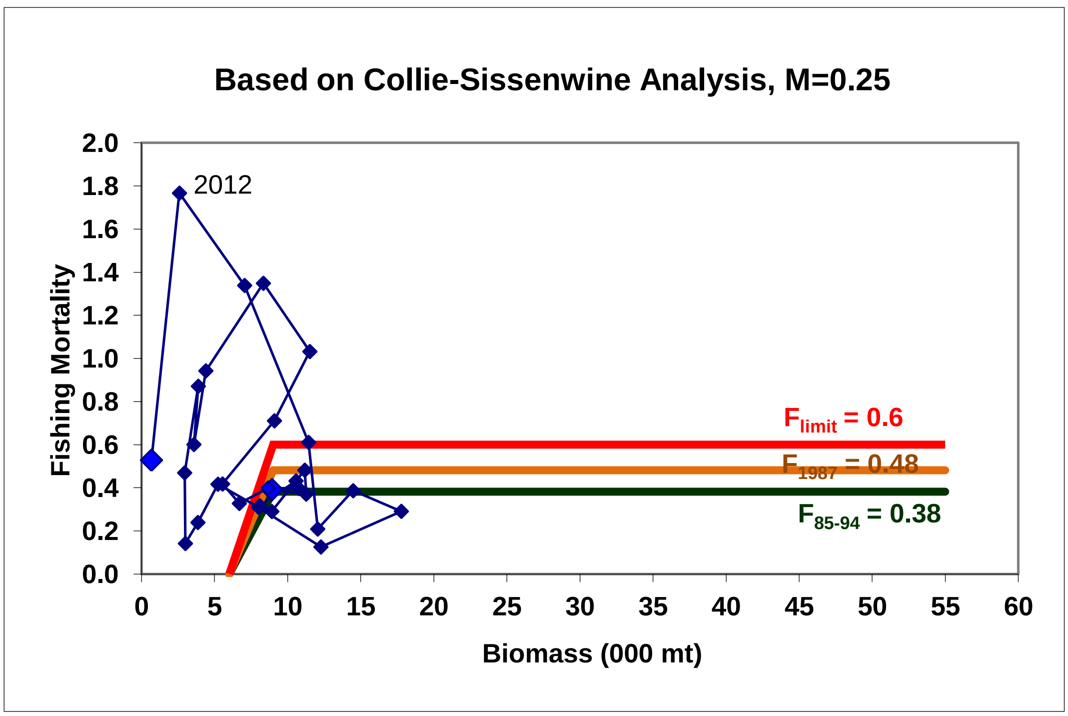


Figure 17. Surplus production of the Gulf of Maine northern shrimp fishery from surplus production (ASPIC, Base Run) (above) and Collie-Sissenwine (CSA with M=0.25) (below) analyses, with fishing mortality and biomass reference points.

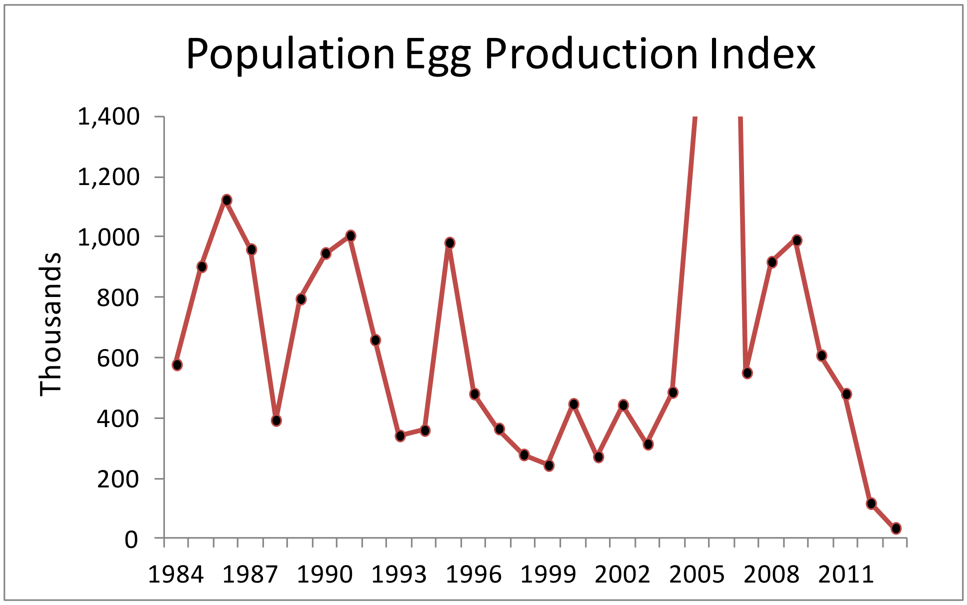


Figure 18. Egg production index based on stratified mean number of females at length from the summer shrimp survey and estimated fecundity at length (Shumway et al. 1985). Estimate for 2006 (off scale) was 4,513,000.

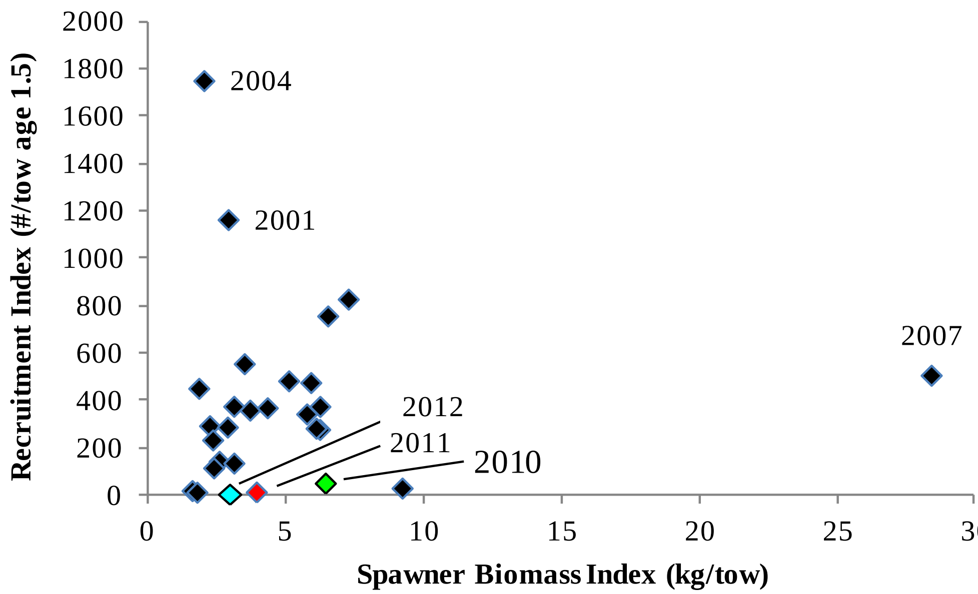


Figure 19. Relationship between summer survey index of Gulf of Maine female northern shrimp biomass the summer before spawning to age 1.5 abundance two years later. Year labels indicate the assumed age 1.5 year class.

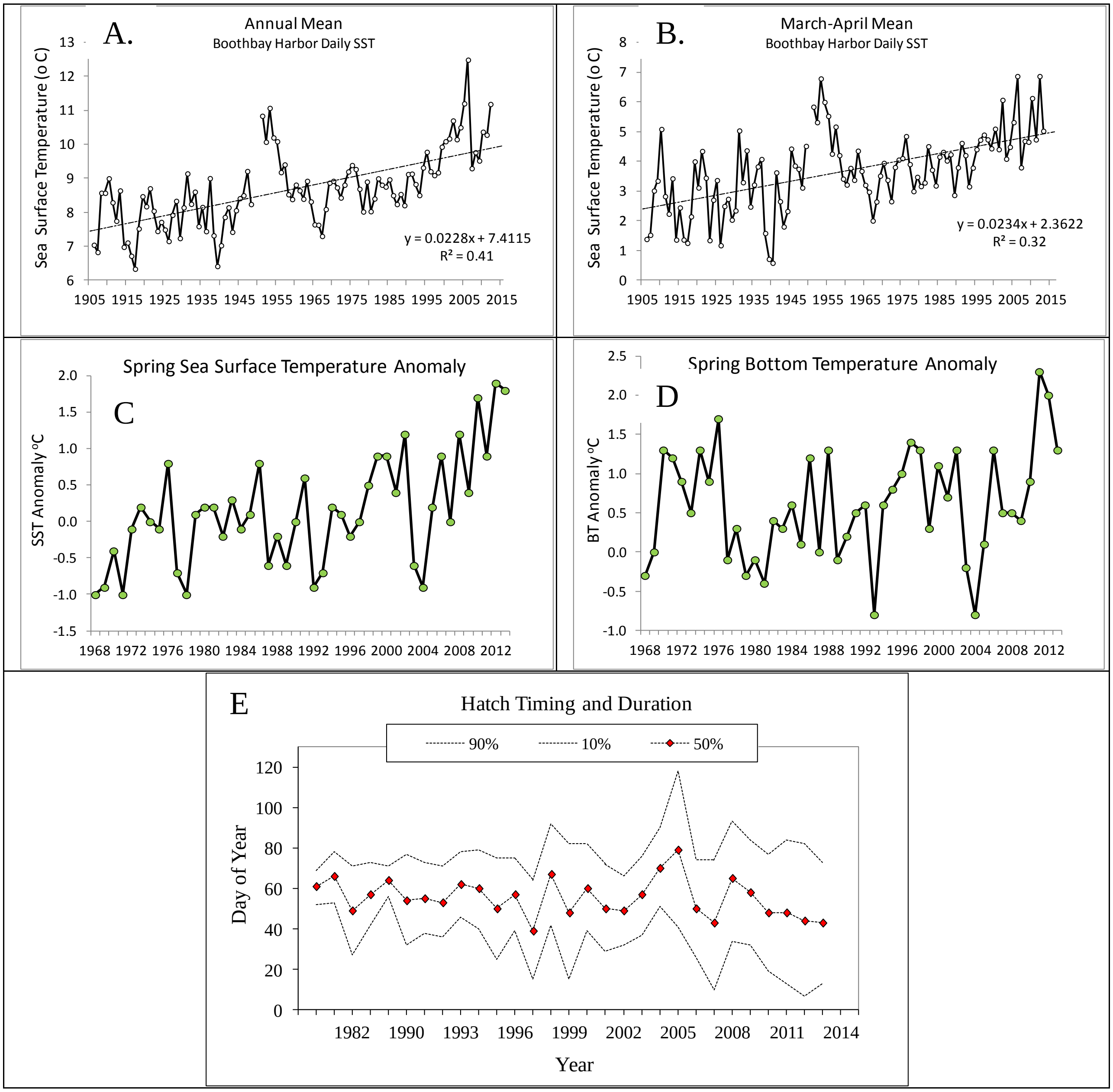


Figure 20. **(A) Average annual sea surface temperature (SST) at Boothbay Harbor, Maine,during 1906-2013 and (B) average SST during March-April, 1906-2013. (C) Spring sea surface temperature anomaly in shrimp offshore habitat areas from NEFSC trawl surveys, 1968-2013. (D) Spring bottom temperature anomaly in shrimp offshore habitat areas from NEFSC trawl surveys, 1968-2013. (E) Estimated hatch timing (10%=start, 50%=midpoint, 90%=completion) for northern shrimp in the Gulf of Maine, 1980-1983 and 1989-2013 (no data 1984-1988).**

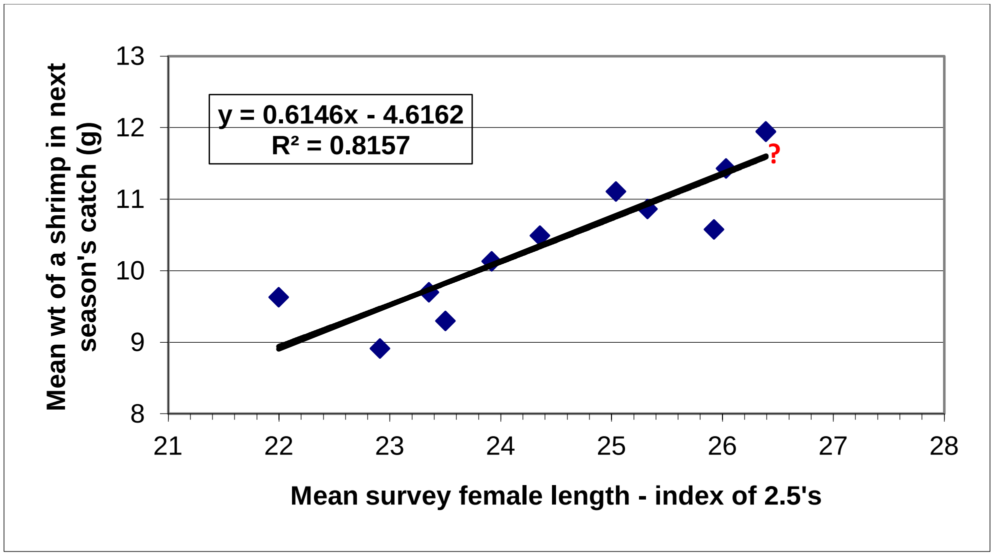


Figure 21. Relationship between the mean weight of a shrimp in the commercial catch and the mean length of female shrimp in the previous year's summer survey adjusted downward by the abundance of assumed 2.5 year-old males. The relationship uses data from 2001-2012 summer surveys, and the 2002-2013 fisheries. "?" indicates survey index during 2013, and predicted size if there were a 2014 fishery.