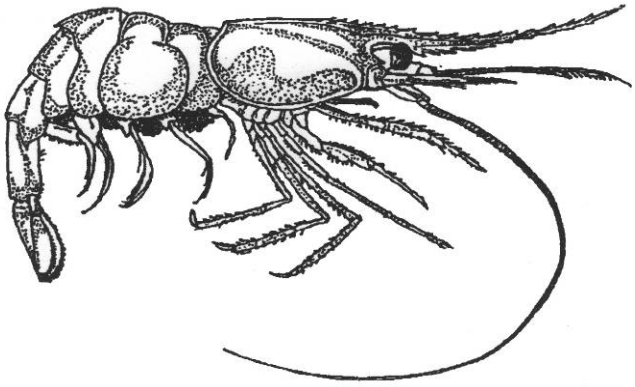
ASSESSMENT REPORT

FOR

GULF OF MAINE NORTHERN SHRIMP – 2008



Prepared

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by the

Atlantic States Marine Fisheries Commission's

Northern Shrimp Technical Committee

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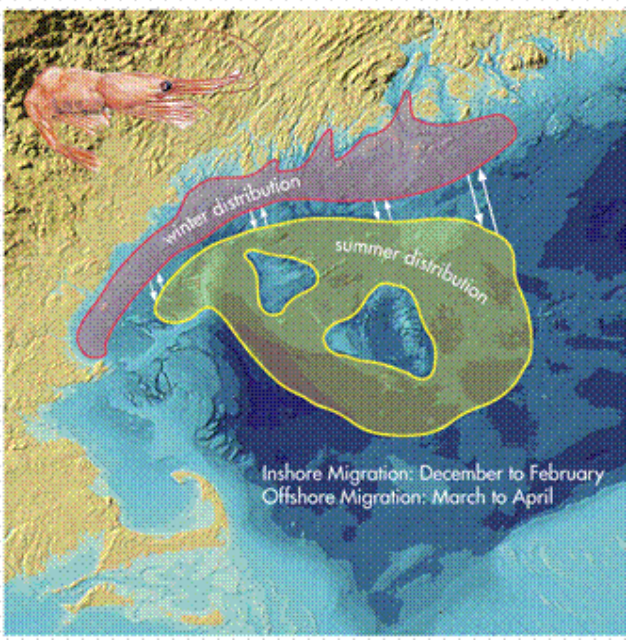
INTRODUCTION

Biological Characteristics



Distribution of adult female northern shrimp, from *Ecosystem Relationships in the Gulf of Maine-Combined Expert Knowledge of Fishermen and Scientists.* NAMA Collaborative Report 1:1-16, 2006.

Northern shrimp (*Pandalus borealis*) are hermaphroditic, maturing first as males at roughly 2½ years of age and then transforming to females at roughly 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 unpredictable. The males pass through a series of transitional stages before maturing as females. Some females may survive to repeat the spawning process in succeeding years. The females are the individuals targeted in the Gulf of Maine fishery. Natural mortality seems to be most pronounced immediately following hatching, and it is believed that most shrimp do not live past age 5.

Fishery Management

The Gulf of Maine fishery for northern shrimp is managed through interstate agreement between the states of Maine, New Hampshire and Massachusetts. The management framework evolved during 1972-1979 under the auspices of the State/Federal Fisheries Management Program. In 1980, this program was restructured as the Interstate Fisheries Management Program (ISFMP) of the Atlantic States Marine Fisheries Commission (ASMFC). The Fishery Management Plan (FMP) for Northern Shrimp was approved under the ISFMP in October 1986 (McInnes, 1986, FMR No. 9). The full Commission in May 2004 approved Amendment 1 to the FMP (ASMFC,

FMR No. 42). Amendment 1, which entirely replaces the original FMP, establishes biological reference points for the first time in the shrimp fishery and expands the tools available to manage the fishery. Any new tools proposed to manage the shrimp fishery must be implemented through the ASMFC addendum process.

Within the ISFMP structure, the Northern Shrimp Technical Committee (NSTC) provides annual stock assessments and related information to the ASMFC Northern Shrimp Section. Annually, the Section decides on management regimes after thorough consideration of the NSTC stock assessment, input from the Northern Shrimp Advisory Panel, and comment from others knowledgeable about the shrimp fishing industry. Management under the 1986 FMP was conducted primarily by seasonal closures and mesh size restrictions and was intended "to optimize yield, recognizing that natural fluctuations in abundance will occur" (McInnes 1986, p ii.). The goal of Amendment 1 is "to manage the northern shrimp fishery in a manner that is biologically, economically, and socially sound, while protecting the resource, its users, and opportunities for participation by all stakeholders."

At its Fall 2007 meeting, the Northern Shrimp Section approved a 152-day season: December 1, 2007, through April 30, 2008, inclusive. This will be referred to as the "2008 season" throughout this document. In addition, it continued to require the use of a finfish excluder device known as the "Nordmore Grate" throughout the shrimp fishing season. The Section also maintained the requirement that made it unlawful to use mechanical "shaking" devices to cull, grade, or separate catches of shrimp. The Section also made a commitment to set a season for 2008 – 2009 that spans the same time frame as the previous season. However, based on information in this assessment, the Section might limit the number of fishing days per week throughout the season.

Fishery Assessment

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

Based on the abundance of the 1992 and 1993 year classes, the NSTC recommended a full season for 1996, but recommended reductions in fishing effort for December, April and May for the 1997 fishery to afford some protection for small shrimp in the offshore areas. The NSTC recommended limiting the fishery to February and March for the 1998 season and a 40-day season during the months of February and March in 1999 to protect the berried females and young shrimp in light of a rapidly declining resource.

The NSTC recommended two options for the 2000 fishing season: 1) closed season; 2) open February 14-March 18 or February 16 - March 14 and May 7-31. Due to an increase in the exploitable biomass in the 2001 season, the Committee recommended a modest increase in landings and a corresponding extension of the season to 61 days. In 2001, however, the low numbers of large shrimp, the lack of new recruits, and the presence of a single year class of medium sized shrimp led the committee to advise that no fishing be conducted in the 2002 season. In 2002, the committee recommended no fishing season that would threaten the reproductive capacity of the 1999 year class or would allow significant catches of the 2001 year class. Again, in 2003 it advised no fishing season to protect the 2001 year class and allow the depressed stock to recover.

The Committee took a different approach in 2004 with regard to its recommendations for the fishery. Instead of recommending a specific season length, it recommended maintaining a target fishing mortality rate below F=0.22. In combination, it strongly urged the Section to craft a season that would not permit landings of more than 2,500 metric tons. This approach was well received by the Advisory Panel and Section and was repeated in 2005, when the Committee recommended that 2006 shrimp landings should be less than 5,200 metric tons. In 2006 the Committee did not oppose another season of 140 days for 2007. In 2007 the Committee recommended maintaining fishing mortality below F=0.22 and did not oppose a 152 day season for 2008.

The following report presents the results of the Technical Committee's 2008 stock assessment. Analyses and recommendations are based on: 1) research vessel survey data collected by the Committee during summer, by the Northeast Fisheries Science Center (NEFSC) during spring

and autumn, and by the Maine-New Hampshire inshore trawl survey, 2) past commercial landings data collected by the National Marine Fisheries Service (NMFS) port agents, 3) biological sampling of the commercial landings by personnel from the participating states and the NMFS, and 4) data from vessel trip reports (VTRs) filed by shrimp fishers. In addition to previously used traditional methods of assessing the stock (i.e. landings data, commercial effort and CPUE estimates, indices of abundance, etc.), more innovative, quantitative tools, such as the Collie-Sissenwine Analysis, ASPIC surplus production, yield per recruit, and eggs per recruit models were introduced in 1997 and continue to be used to provide guidance for management of the stock.

COMMERCIAL FISHERY TRENDS

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 2,300-4,400 mt during 1988-1994, and then rose dramatically to 9,200 mt in 1996, the highest since 1973. Landings declined to an average of 1,800 mt for 1999 to 2001, and dropped further in the 25-day 2002 season to 424 mt, the lowest northern shrimp landings since the fishery was closed in 1978. Landings have increased steadily since then, averaging 2,000 mt during the 2003 to 2006 seasons, and then jumped to 4,100 mt in the 2007 season (preliminary data). Preliminary landings for the 2008 season (152 days) were 4,800 mt. (Table 1 and Figure 1).

Maine landed 91% (4,359mt) of the 2008 season total, while New Hampshire and Massachusetts landed 8.4% (399mt) and 0.5% (26mt), respectively (preliminary data, Table 1). The proportional distribution of landings among the states was similar to 2003-2007, 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 (Table 2 and Figure 2a, preliminary data) remained generally similar to past years. The month of February 2008 (29 open days) yielded the highest proportion of the catch (45%) and the greatest catch per open day. January was lower than in some years (23%). April (30 open days) exhibited the lowest proportion of the catch (1%) and the lowest catch per open day – lower than in other years, because harvesters didn't fish during the second half of the month, citing high fuel prices and low prices for shrimp.

Most northern shrimp fishing in the Gulf of Maine is conducted by otter trawls, although traps are also employed off the central Maine coast. According to federal and state of Maine Vessel Trip Reports (VTRs), trappers averaged 13% of Maine's landings during 2001 to 2007 (preliminary data), and 18% (preliminary data) in 2008 (Table 3).

Size, Sex, and Maturity Stage Composition of Landings

Size composition data (Figures 3-5), collected from catches since the early 1980s, indicate that trends in landings have been determined primarily by recruitment of strong (dominant) year classes. Landings more than tripled with recruitment of a strong assumed 1982 year class in 1985 – 1987 and then declined sharply in 1988. A strong 1987 year class was a major contributor to the 1990-1992 fisheries. A strong 1992 year class, supplemented by a moderate 1993 year class, partially supported large annual landings in 1995 – 1998. Low landings in 1999 – 2003 were due in part to poor 1994, 1995, 1997, 1998, and 2000 year classes with only moderate 1996 and 1999 year classes. Catches in 2004 were composed primarily of egg bearing, early maturing, presumed three-year-old females from the 2001 year class and a few larger females from the 1999 year-class. In 2005, catches were composed of egg bearing females and female II's from the presumed 2001 year class and males from the 2003 year class. 2006 catches were composed of egg bearing and female II's, probably from the strong 2001 year class. Catches in March and April had substantial numbers of smaller shrimp, presumably from the 2003 (transitionals and female I's) and 2004 (juveniles and males) year classes. In the 2007 fishery, landings were mostly composed of assumed 4-year-old females from the moderate to strong 2003 year class, and possibly 6-year-olds from the 2001 year class. Males, transitionals, and female I's from the strong assumed 2004 year class were also evident, as well as a few small males from the 2005 year class. In the 2008 fishery, landings were mostly composed of the

assumed 4 year-old females from the strong 2004 year class, the 2003 year class (assumed 5 year–old females, which first appeared as a moderate year class in 2004), and some males and transitionals from the moderate 2005 year class. There were also a few juveniles in the <10-13mm size range from the assumed 2007 year class (Figure 5).

Maine trappers landed fewer small shrimp, and generally were more apt to catch large females after egg hatch, than trawlers, as in previous years (Figure 3). See the table below for the average counts per pound by month and gear.

2008 commercial shrimp fishery average counts per pound, from port samples

	***Pandalus borealis* only**					**All shrimp species**				
	Dec.	Jan.	Feb.	Mar.	Apr.	Dec.	Jan.	Feb.	Mar.	Apr.
Maine Trawls	53	46	47	48	57	55	48	50	50	57
Maine Traps	n/a	42	43	42	n/a	n/a	44	44	43	n/a
Maine Total	53	46	45	46	57	55	48	47	47	57
Massachusetts	59	59	n/a	61	n/a	59	72	n/a	61	n/a
New Hampshire	50	60	50	51	n/a	50	60	52	53	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). According to port samples, in December 2007, in Maine, 2.6% of the trawled catch was female stage II; in January 2008 this increased to 5.4% and in February it increased to 13.5%. In March and April, female stage II's further increased to 48.7% and 57.2% respectively. As the 2008 season progressed, all months showed a reduction in the proportion of females carrying eggs with no eggs being carried in Maine samples in April. Note that egg hatch in the 2008 season was later than in the 2007 and 2006 seasons. Maine trappers caught 3.6% female stage II in January 2008, 26.7% in February, and 73.1% in March, consistently higher than the trawl catches each month but not as high as trap catches in 2007 and 2006 (Figure 3).

In Massachusetts and New Hampshire trawl catch samples combined, the percentage of female stage II shrimp was 0.9% in December 2007, 13.9% in January 2008, 49.4% in February, 55.4% in March and 84.8% in April (Figure 4), probably reflecting the eastern Gulf lagging the west in the timing of egg hatch.

Discards

Port samplers did not report hearing about any shaking of catches to remove small northern shrimp during the 2008 season. Maine trappers do manually shake out the smaller pandalid species of veined or striped shrimp (*Pandalus montagui* and *Dichelopandalus leptocerus*) on occasion. During the middle of January, a few trawler captains from eastern Maine reported substantial bycatch of the sand shrimp, *Crangon septemspinosa*.

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 & Yevitch, 1974). Its etiology is unknown, although fungal and ciliated protist parasites have been implicated. In samples collected in Maine during the 2004 – 2008 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 late 1970's, effort in the fishery (measured by numbers of trips in which shrimp gear is used) has increased and then declined on three occasions. The total number of trawl trips in the fishery (Table 4 and Figure 6a) peaked at 12,285 during the 1987 season. Increases in season length, shrimp abundance, and record ex-vessel prices, coupled with reduced abundance of groundfish, all contributed to this increase. Effort subsequently fell to 5,990 trips in the 1994 season. Effort nearly doubled between 1994 and 1996 and then declined again from the 1996 level of 11,791 to 1,010 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 2,962 trawl trips in 2005. Trips in 2006 dropped to 1,557, likely due to poor market conditions, increased in 2007 to 2,605 (preliminary), and increased in 2008 to 3,785 (preliminary, Table 4), the most since 1999. Please note that in the 2006 and 2007 assessments, the trips reported for 2004 to 2007 were

miscalculated (overestimated by about 7%) and have been corrected in Table 4 and Figure 6a here.

The number of vessels participating in the fishery in recent years has varied from a high of 347 in 1996 to a low of 142 in 2006 (Table 6). In 2008, there were 211 vessels from Maine, 5 from Massachusetts, and 14 from New Hampshire, for a total of 230, according to federal VTR and Maine harvester logbook data (preliminary). Of these, 91 of the Maine boats were trapping.

Maine trapping operations accounted for an average of 22% of the Maine shrimp fishing trips in 2001 - 2005. This number has gradually increased, to 32% for 2006 - 2008, according to VTRs (preliminary, Table 5).

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 2007 and 2008 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. In the 2008 season in Maine, sampled trawl trips were about 75% offshore in December, decreasing to about 10% in January, February, and March, and 100% offshore in April, based on a total of 160 trawler interviews. In Massachusetts and New Hampshire, all sampled December trips were offshore, half the January trips were offshore, and all the sampled February and March trips were inshore, based on a total of 22 interviews. Overall, the proportion of offshore trips was lower in 2008 than in previous seasons, perhaps because of increased fuel costs.

Locations of 2008 fishing trips and landings from federal VTRs are plotted by 10-minute square in Figure 7.

Catch per Unit Effort

Catch per unit effort (CPUE) indices have been developed from NMFS interview data (1983-1994) and logbook data (1995-2008) and are measures of resource abundance and availability. (See Table 7 and Figure 6). They are typically measured in catch per hour (from state interview data) or catch per trip. A trip is a less precise measure of effort, because trips from interviews and logbooks include both single day trips and multiple day trips (in the spring), and the proportion of such trips can vary from season to season.

Pounds landed per trawl trip, from VTRs, averaged 1,393 pounds during 1995-2000. In 2001, the catch per trip dropped to 740 pounds, the lowest since 1988, and remained low, at 831 pounds, in 2002. During 2003 – 2005 it averaged 1,533 lbs/trip; in 2006 it was 2,562, in 2007 it was 3,106 pounds per trip (preliminary), the highest in the time series, and in 2008, it was 2,278 (preliminary), still well above average (Figure 6b).

More precise CPUE indices (pounds landed per hour fished) have also been developed for both inshore (depth less than 55 fathoms) and offshore (depth more than 55 fathoms) areas using information collected by Maine's port sampling program, and agree well with the (less precise) catch per trip data from logbooks (see Table 7 and Figure 6b). Maine inshore CPUE for 2008 was 350 lbs/hr, offshore was 327 lbs/hr, and the season average was 343 lbs/hr, well above the time series average of 229 lbs/hr.

RESOURCE CONDITIONS

Trends in abundance 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 during the fall of 2000 (Sherman et al. 2005). A state-federal shrimp survey was initiated by the NSTC in 1984. The latter survey is conducted each summer aboard the *R/V Gloria Michelle* employing a stratified random sampling design and gear specifically designed for Gulf of Maine conditions. The NSTC has placed primary dependence on the summer survey for fishery-independent data used in stock assessments, although other survey data have been valuable as well.

There has generally been good agreement between the NEFSC autumn survey index and fishery trends (Table 11, stratified mean Fall kg per tow, and Figures 8c and 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 1.17 kg/tow in 1996, the index rose sharply in 1998 and 1999 to 2.26 and 2.39 kg per tow respectively, both well above the time series mean of 1.84 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. Since 2002, the index has generally increased, reaching unprecedented time series highs in 2006 and 2007 of 7.09 kg/tow and 5.54 kg/tow, respectively. Since 2002, landings have also generally risen each year, although the recent resource highs were not reflected in the fishery, likely due to poor market conditions for shrimp. Elevated fall survey indices observed since 2002 are indicative of robust assumed 2001 and 2004 year classes and moderate 2003 and 2005 year classes.

The Maine-New Hampshire inshore trawl survey took place in 5 regions and 3 depth strata (1=5-20 fa, 2=21-35 fa, 3=36-55 fa) until a deeper stratum (4, > 55 fa) was added in 2003 (Figure 8a). The survey consistently caught shrimp in regions 1-4 (NH to Mt. Desert) and depths 3-4 (> 35 fa), and more were 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 Table 8 and Figure 10. This index has risen from 4.22 kg/tow during spring 2003 to 14.79 kg/tow during spring 2008 (preliminary data).

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the state-federal summer survey from 1984-2008 are given in Table 9 and Figures 8b and 11, and length-frequencies by year are provided in Figure 12. The $\log_e$ transformed mean weight per tow averaged 15.8 kg/tow from 1984 through 1990. Beginning in 1991 this index began to decline and averaged 10.2 kg/tow from 1991 through 1996. The index then declined further, averaging 6.1 kg/tow from 1997 through 2001, and reaching a time series low of 4.3 kg/tow in 2001. In 2002 the index increased to 9.2 kg/tow, and then declined to the second lowest value in the time series (5.5 kg/tow) in 2003. Since 2003, the index has increased markedly, reaching a new time series high in 2006 (66.0 kg/tow). This trend should be viewed with caution because the 2006 summer survey indices were based on 29 tows, compared with about 40 tows in most years (Table 9). In 2007, with 43 tows conducted, the index decreased to 11.5 kg/tow and in 2008 the index was 16.8 kg/tow with 38 tows completed. The total mean number 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 1987, 1992, 2001, and 2004 year classes, and moderately strong year classes for 1990 and 1999. The 1997 and 1998 age classes were weak, both well below the time series mean of 392 individuals per tow. In 2001 the age 1.5 recruitment index was at its lowest level since 1984, with a stratified mean of 18 individuals per tow on the transformed scale, representing recruitment failure of the 2000 year class. In 2002 the age 1.5 recruitment index increased dramatically to 1,164, which was the time series high and represents an extremely strong 2001 year class. It is interesting to note that in the 2002 summer survey, more small females (< 19 mm CL, assumed 1.5 years old) were caught than at any other time in the history of the survey (Figure 9). The index subsequently dropped to 11 individuals per tow in 2003, indicating a very poor 2002 year class, the worst in the time series. The index increased in 2004 to 286 individuals per tow, and reached a time series high in 2005 (1,753 individuals per tow). This is indicative of a moderate 2003 year class and a very strong 2004 year class. The age 1.5 recruitment index dropped in 2006 (374 individuals per tow) and again in 2007 (28 individuals per tow), indicating a moderate 2005 year class and very weak 2006 year class. The index increased to 508 individuals per tow in 2008, indicating a moderate but above average 2007 year class.

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

female stage 1 shrimp (Figure 9), probably the 2003 year class. In 2007 the index declined to 4.1 kg/tow with the passing of the 2001 year class and the diminishing of the 2003 year class. The moderate 2007 index was unlike many other years in that individuals >22 mm included a relatively even mix of males, female stage I, and female stage II shrimp (Figure 12). The 2008 index increase to 10.8 kg/tow and was composed of a moderate number of males and female stage II shrimp, reflecting the strong 2004 and moderate 2005 year classes.

ANALYTICAL STOCK ASSESSMENT

Descriptive information for the Gulf of Maine shrimp fishery (total catch, port sampling, trawl selectivity, survey catches, and life history studies) were modeled to estimate fishing mortality, stock abundance, and candidate target fishing levels. The analytical stock assessment comprises three fishery models: the Collie-Sissenwine Analysis (CSA) (Collie and Sissenwine 1983; Collie and Kruse 1998) tracks the removals of shrimp using summer survey indices of recruits and fully-recruited shrimp scaled to total catch in numbers; surplus production analysis models the biomass dynamics of the stock with a longer time series of total landings and three survey indices of stock biomass; a yield-per-recruit and eggs-per-recruit model simulates the life history of shrimp (including growth rates, transition rates, natural mortality, and fecundity) and fishing mortality on recruited shrimp using estimates of trawl selectivity to estimate yield and egg production at various levels of fishing mortality, for guidance in determining the levels of fishing that are most productive and sustainable. See the Appendix for a discussion of natural mortality rates (M).

CSA results, assuming M=0.25, are summarized in Table 10 and Figures 13 and 14 – see the Appendix for results with M=0.40 and M=0.60. Abundance and catchability were relatively well estimated, and the model fit the data well. Estimates of recruitment to the fishery averaged 0.7 billion individuals between 1985 and 1990, declining (average 0.5 billion) through 1991 to 1994. Recruit abundance rose to 0.9 billion before the 1996 fishing season, then declined steadily to less than 0.3 billion before the 2002 fishing season. Estimates of 2.0 billion (2006 and 2007 respectively) are the highest seen (from 1984 through 2008). Current abundance of recruits is estimated to be 0.9 billion. Fully-recruited abundance averaged 1.0 billion individuals and

peaked at 1.1 billion before the 1991 season. Since that point, fully-recruited abundance declined steadily to 0.3 billion before 2001, and then increased to 2.8 billion before 2008, then declined to 2.2 billion in the current year. Total stock biomass estimates averaged about 13,800 mt through 1996 and decreased to a time series low of 4,700 mt before 2001. Total stock biomass has increased over recent years to its current value of 27,900 mt, down slightly from the series high of 30,100 mt before 2007 (Table 10, Figures 13, 14).

Annual estimates of fishing mortality (F) averaged 0.24 (18% exploitation) for the 1985 to 1994 fishing seasons, peaked at 1.01 (57% exploitation) in the 1997 season and decreased to 0.08 (7% exploitation) in 2002 (Table 10; Figures 13, 14). These declines were due in part to a short season and poor stock conditions. Continued poor stock conditions (in terms of exploitable shrimp) along with an exceptional recruitment pulse resulted in F rising to 0.22 (17% exploitation) in 2004. The 2008 estimate of F is 0.18 (14% exploitation). Recent patterns in F reflect the pattern in nominal fishing effort (Tables 4 and 10, Figures 6 and 13).

Precision of CSA estimates was assessed by "bootstrap" analysis, in which survey measurement errors were randomly shuffled 2000 times to provide simulated replications of the model. Bootstrap results suggest that estimates of abundance, biomass and mortality were relatively precise (Figure 13).

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

An alternative method of estimating stock size and F was used to corroborate results from CSA analysis. A surplus production model (ASPIC) was fit to seasonal catch and survey biomass indices from 1968 to 2008 (summarized in Table 11). F in 2008 (F = 0.15) is below the fishing mortality target/threshold (F = 0.22) established in Amendment 1 to the northern shrimp Fishery Management Plan. The 2008 starting biomass (31,650 mt) was at its highest level since 1971, and is above the average observed in the time period from 1985 through 1994 when the Gulf of Maine Northern shrimp biomass was stable (13,570 mt).

Precision of surplus production model estimates was assessed by "bootstrap" analysis, in which survey measurement errors were randomly sampled 1000 times to provide simulated replications of the model. Bootstrap results suggest that estimates of biomass and mortality were relatively precise.

Estimates of F and Biomass from the surplus production model generally confirmed the pattern of estimates from the CSA model between 1985 and 2007 (Figures 15 and 16). However, there is some divergence in the trend in biomass seen for terminal years (2008 and 2009), where the surplus production model trends upward and the CSA trends downward minimally. The terminal year values of fishing mortality and biomass in both models are typically poorly estimated.

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

As concluded by the Stock Assessment Review Committee (SARC) (NEFSC 1996), the stock was not replacing itself when spawning potential was reduced to less than 20% of maximum, and the stock collapsed when egg production was reduced further. Reproductive success for Gulf of Maine northern shrimp may be a function of population fecundity and spring seawater temperature (Figure 19). Therefore, $F_{20\%}$ may be an appropriate overfishing threshold, which would result in a target F well below 0.6. A sustainable target F may be the average F from 1985 through 1994, which was 0.24 (which allows 50% egg production per recruit) (Table 12, Figure 17).

SUMMARY

Landings in the Gulf of Maine northern shrimp fishery declined after the mid 1990's, from a high of 9,166 mt in 1996 to a low of 424 mt in 2002, the result of low abundances of shrimp and

reductions in fishing effort. Since then, landings have increased to 4,783 mt in the 152-day 2008 season (preliminary). The 2008 season was characterized by high catch rates, poor price, and high fuel costs. 2008 landings were comprised mostly of assumed 4-year-old female shrimp from the strong 2004 year class.

The number of fishing vessels and trawl trips dropped from about 347 and 11,791 respectively in 1996 to 150 and 1,010 in 2002, then increased to 230 and 3,785 respectively in 2008 (preliminary). Of the 230 vessels that reported shrimp landings in 2008, 91 were trapping, and trappers accounted for about 16% of the landings.

Fishing mortality rates (F), as calculated by CSA, declined from 1.01 in 1997 to 0.08 in 2002, then rose to 0.18 in the 2008 fishery (preliminary). F was above the 1985-1994 average (the target or threshold F in the FMP) every year from 1995 through 2001.

Current landings, vessels, and trips, are calculated from vessel trip reports (federal and Maine state VTRs). Note that 2007 landings were incomplete when calculated in September of 2007 (Table 1 of the 2007 assessment report), and went up by 21% when recalculated in September 2008 (Table 1 here). Thus it must be assumed that 2008 vessel trip reports are also incomplete at this time, but note that Maine improved report compliance enforcement during 2008.

Exploitable biomass as estimated from CSA declined from 14,000 mt at the beginning of the 1996 season to a time series low of 4,700 before 2001. Since then the biomass estimate has risen to 11,900 mt before 2005, as a result of the appearance of the strong 2001 year class, and to 27,900 mt for the 2009 season, driven by a strong 2004 year class and high summer survey indices for 2005 and 2006. The technical committee notes that there is a high degree of uncertainty around terminal year estimates, however. Exceptionally high survey indices from the 2006 summer survey, which had fewer tows than usual, also add a source of uncertainty.

Size composition data from both the fishery and summer surveys indicate that good landings have followed the recruitment of strong (dominant) year classes. Poor landings from 1998 to 2004, as well as low biomass estimates, can be attributed in part to the below-average

recruitment of the assumed 1994, 1995, 1997, 1998, 2000, and 2002 year classes. In 2009, the very strong 2004 year class (assumed 5-year-old females), will contribute most to landings, the moderate 2005 year class will be assumed 4-year-old females and transitionals, and the weak 2006 year class and above-average 2007 year class will be transitionals, males, and juveniles.

RECOMMENDATIONS

The Northern Shrimp Technical Committee bases its recommendations to the Section on its assessment of current stock status, the biology of the species, and the stated management goal of protecting and maintaining the stock at levels that will support a viable fishery (Amendment 1 to the FMP, ASMFC 2004).

The committee recommends that the Section continue its recent efforts to maintain fishing mortality at or below the FMP target/threshold value of 0.22. The strong 2004 year class and the arrival of the above-average 2007 year class present welcome opportunities to continue rebuilding the stock. A very weak 2006 year class continues to be a concern.

Short-term commercial prospects are good; the abundance of shrimp of length greater than 22 mm is above the average value for the 1984-2008 survey period. If these shrimp follow traditional patterns of migrating and aggregating behavior, the 2009 fishery can anticipate good catches at current levels of fishing effort. Because of the relative strength of the 2004 year class compared with 2005, we expect catches in 2009 to be comprised of mostly 5-year-old female shrimp, with counts per pound similar to those in the 2006 fishery, when the 2001 year class was the dominant component of the landings. However, if the female shrimp fail to separate themselves from the smaller males, or if the fishery is conducted when the year classes are mixed, a “mixy” product will result, and an opportunity to husband the smaller shrimp will be lost.

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

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

Using this relationship, the estimated abundance of recruits and new recruits for survey year 2008 (from Figure 14), an estimate of 0.25 for M, and assuming size distributions in the 2009 landings will be similar to the 2006 fishery's distribution with a mean size of 10.83g per shrimp, it is possible to estimate landings for different levels of F:

Fishing Mortality Rate for 2009	Estimated Landings (mt)	Estimated Landings (lbs)
0.05	1,256	2,768,962
0.10	2,453	5,408,498
0.15	3,594	7,924,787
0.20	4,682	10,323,708
0.22	**5,103**	**11,251,676**
0.25	5,719	12,610,859
0.30	6,708	14,791,568
0.40	8,550	18,853,705
0.50	10,226	22,547,834
0.60	11,750	25,908,132
0.75	13,782	30,389,597
1.00	16,593	36,588,517
1.25	18,820	41,498,345

Therefore, **the committee recommends a 2009 shrimp landings level at or below 5,103 mt**, similar to the 2008 season landings. If shrimp smaller than 10.83g are caught in substantial numbers, the fishing mortality rate (F) will be higher for the same landed weight.

Yield-per-recruit and egg-per-recruit analyses (Table 12) show that shrimp reach both their potential maximum weight yield and maximum egg production at about ages 4-5. Therefore, protecting younger shrimp and late-maturing males is recommended for both economical and biological reasons. Protecting egg-bearing females prior to egg hatch, which usually occurs during February and/or March, is also recommended.

The committee notes the uncertainty in the estimates of F and stock abundance associated with the terminal years of the CSA model, particularly when landings data are incomplete. There is also considerable uncertainty in projecting the exploitable biomass from the time of the summer survey to the fishing season, and in predicting the size distribution of the catch in the upcoming

season. The committee urges caution in selecting management options, since estimates of both F and stock abundance are subject to change in either direction, that is, these parameters may be over- or underestimated in any given year.

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

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Table 1. Commercial landings (mt) of northern shrimp in the western Gulf of Maine, 1958-2008.

Year	Maine		Massachusetts		New Hampshire		Total		Price
	Annual	Season	Annual	Season	Annual	Season	Annual	Season	$/Lb
1958	2.3		0.0		0.0		2.3		0.32
1959	5.4		2.3		0.0		7.7		0.29
1960	40.4		0.5		0.0		40.9		0.23
1961	30.4		0.5		0.0		30.9		0.20
1962	159.7		16.3		0.0		176.0		0.15
1963	244.0		10.4		0.0		254.4		0.12
1964	419.4		3.1		0.0		422.5		0.12
1965	947.0		8.0		0.0		955.0		0.12
1966	1,737.8		10.5		18.1		1,766.4		0.14
1967	3,141.1		10.0		20.0		3,171.1		0.12
1968	6,515.0		51.9		43.1		6,610.0		0.11
1969	10,992.9		1,772.9		58.1		12,823.9		0.12
1970	7,712.8		2,902.1		54.4		10,669.3		0.20
1971	8,354.7		2,723.8		50.8		11,129.3		0.19
1972	7,515.6		3,504.5		74.8		11,094.9		0.19
1973	5,476.7		3,868.2		59.9		9,404.8		0.27
1974	4,430.7		3,477.3		36.7		7,944.7		0.32
1975	3,177.0		2,080.2		29.5		5,286.7		0.26
1976	617.2		397.8		7.3		1,022.3		0.34
1977	148.0		236.9		2.3		387.2		0.55
1978	0.0		0.0		0.0		0.0		0.24
1979	32.9		451.3		2.3		486.5		0.33
1980	71.4		260.3		7.4		339.1		0.65
1981	528.6		538.1		4.5		1,071.2		0.64
1982	883.2	853.3	658.5	655.3	32.8	21.6	1,574.5	1,530.2	0.60
1983	1,022.0	892.5	508.0	458.4	36.5	46.2	1,566.5	1,397.1	0.67
1984	2,564.7	2,394.9	565.3	525.1	96.8	30.7	3,226.8	2,950.7	0.49
1985	2,956.9	2,946.4	1,030.6	968.0	207.4	216.5	4,194.9	4,130.9	0.44
1986	3,407.3	3,268.2	1,085.6	1,136.3	191.1	230.5	4,684.0	4,635.0	0.63
1987	3,534.2	3,673.2	1,338.7	1,422.2	152.5	157.8	5,025.4	5,253.2	1.10
1988	2,272.4	2,257.2	631.5	619.6	173.1	154.5	3,077.0	3,031.3	1.10
1989	2,542.6	2,384.0	749.6	699.9	314.3	231.5	3,606.5	3,315.4	0.98
1990	2,961.5	3,236.1	993.2	974.3	447.3	451.2	4,402.0	4,661.6	0.72
1991	2,431.1	2,488.1	727.6	801.1	208.2	282.2	3,366.9	3,571.4	0.93
1992	2,973.9	3,054.1	291.6	289.1	100.1	100.0	3,365.6	3,443.6	0.99
1993	1,562.8	1,492.2	300.3	292.8	441.1	357.4	2,304.7	2,142.9	1.03
1994	2,815.5	2,239.3	374.4	247.5	520.9	428.0	3,710.8	2,914.8	0.79
1995		5,022.7		678.8		764.9		6,466.4	0.88
1996		7,737.0		658.0		771.0		9,166.1	0.72
1997		6,050.0		362.8		666.3		7,079.1	0.82
1998		3,482.0		247.2		445.2		4,174.4	0.94
1999		1,523.4		75.7		217.0		1,816.1	0.93
2000		2,067.3		109.9		212.3		2,389.5	0.79
2001		1,073.4		49.2		206.4		1,329.1	0.86
**2002		364.8		7.7		51.2		423.7	1.07
**2003		1,081.2		23.1		106.7		1,211.0	0.87
**2004		1,752.7		17.5		174.6		1,944.8	0.45
2005		2,227.8		48.1		289.8		2,565.7	0.56
2006		1,965.9		24.8		90.2		2,080.9	0.37
**2007		3,765.6		10.3		290.2		4,066.1	0.39
2008		4,358.6		25.8		399.2		4,783.5	

**Includes removals by experimental studies

2007 and 2008 are preliminary.

Table 2. Distribution of landings (metric tons) in the Gulf of Maine northern shrimp fishery by state and month, 1987 - 2008.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1987 Season, 182 days, Dec 1 - May 31								
Maine	485.9	906.2	1,192.7	672.9	287.6	127.9	7.0	3,680.2
Mass.	103.5	260.0	384.9	310.2	180.8	182.8	5.7	1,427.9
N.H.	18.4	53.6	62.8	15.7	7.3	0.0	0.1	157.9
Total	607.8	1,219.8	1,640.4	998.8	475.7	310.7	12.8	5,266.0
1988 Season, 183 days, Dec 1 - May 31								
Maine	339.7	793.9	788.1	243.6	24.6	67.3	1.2	2,258.4
Mass.	14.4	225.8	255.0	104.9	8.6	10.9	0.0	619.6
N.H.	13.0	72.6	53.7	14.9	0.3	0.0	3.1	157.6
Total	367.1	1,092.3	1,096.8	363.4	33.5	78.2	4.3	3,035.6
1989 Season, 182 days, Dec 1 - May 31								
Maine	353.6	770.5	700.6	246.4	218.7	94.2		2,384.0
Mass.	26.2	197.5	154.9	104.8	160.9	55.6		699.9
N.H.	28.5	106.9	77.0	15.4	3.7	0.0		231.5
Total	408.3	1,074.9	932.5	366.6	383.3	149.8		3,315.4
1990 Season, 182 days, Dec 1 - May 31								
Maine	512.4	778.2	509.7	638.5	514.0	282.8	0.1	3,235.7
Mass.	75.6	344.4	184.8	100.2	158.9	110.0	4.3	978.2
N.H.	111.3	191.7	116.1	30.7	1.4			451.2
Total	699.3	1,314.3	810.6	769.4	674.3	392.8	4.4	4,665.1
1991 Season, 182 days, Dec 1 - May 31								
Maine	238.2	509.1	884.0	454.9	251.7	148.2	2.0	2,488.1
Mass.	90.5	174.7	175.9	131.2	93.3	133.8	1.6	801.0
N.H.	107.3	104.4	33.8	27.8	7.8	1.0		282.1
Total	436.0	788.2	1,093.7	613.9	352.8	283.0	3.6	3,571.2
1992 Season, 153 days, Dec 15 - May 15								
Maine	181.1	880.9	1,278.9	462.5	163.6	87.2		3,054.2
Mass.	17.1	148.2	73.3	47.5	2.9		0.1	289.1
N.H.	33.4	47.0	11.9	6.8	1.0			100.1
Total	231.6	1,076.1	1,364.1	516.8	167.5	87.2	0.4	3,443.7
1993 Season, 138 days, Dec 14 - April 30								
Maine	100.9	369.0	597.0	297.5	127.8			1,492.2
Mass.	19.6	82.0	81.9	62.3	42.0	5.0		292.8
N.H.	33.5	85.4	101.7	77.0	59.8			357.4
Total	154.0	536.4	780.6	436.8	229.6	5.0	0.4	2,142.8
1994 Season, 122 days, Dec 15 - Apr 15								
Maine	171.5	647.7	971.9	399.5	48.7			2,239.3
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	840.0	1,201.4	487.9	69.7			2,914.8

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	747.6	1,397.7	1,338.2	912.0	627.2			5,022.7
Mass.	210.7	154.0	104.1	111.0	99.0			678.8
N.H.	160.6	186.8	118.3	158.5	140.7			764.9
Total	1,118.9	1,738.5	1,560.6	1,181.5	866.9			6,466.4
1996 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	1,124.1	1,678.3	3,004.6	785.2	350.4	794.5		7,737.1
Mass.	167.9	106.7	188.7	67.8	66.5	60.3		657.9
N.H.	189.8	169.5	234.0	81.9	78.8	17.1		771.1
Total	1,481.8	1,954.5	3,427.3	934.9	495.7	871.9		9,166.1
1997 Season, 156 days, Dec 1- May 27, two 5-day and four 4-day blocks off								
Maine	1,178.5	1,114.9	1,713.1	758.4	754.8	530.3		6,050.0
Mass.	90.2	110.4	111.4	49.0	1.2	0.5		362.7
N.H.	185.6	104.1	140.1	108.6	85.8	42.2		666.4
Total	1,454.3	1,329.4	1,964.6	916.0	841.8	573.0		7,079.1
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	401.7	228.7	202.6		3,482.0
Mass.	49.1	78.0	90.5	14.3	15.3	0.0		247.2
N.H.	89.4	106.9	143.5	54.3	49.0	2.1		445.2
Total	649.6	1,111.7	1,445.1	470.3	293.0	204.7		4,174.4
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	590.8	240.6	204.5	214.9		1,523.4
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	659.0	253.1	249.4	223.5		1,816.1
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		607.4	1,271.4	188.5				2,067.3
Mass.		17.4	78.7	13.8				109.9
N.H.		39.6	131.1	41.6				212.3
Total		664.4	1,481.2	243.9				2,389.5
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May								
Maine		576.0	433.5	37.1	26.5	0.3		1,073.4
Mass.		38.5	8.9	1.9	0.0	0.0		49.2
N.H.		127.9	37.4	12.1	29.0	0.0		206.4
Total		742.4	479.8	51.1	55.5	0.3		1,329.1
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			285.5	76.7			2.5	364.8
Mass.			5.3	2.3			0.01	7.7
N.H.			38.0	13.3				51.2
Total			328.8	92.4			2.5	423.7

Table 2 continued.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		477.5	602.4	1.2			0.02	1,081.2
Mass.		10.5	12.6					23.1
N.H.		28.2	78.5					106.7
Total		516.2	693.5				0.02	1,211.0
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	1.8	522.3	845.1	376.1	4.7	2.7	0.0	1,752.7
Mass.		5.2	10.1	2.1				17.5
N.H.		27.0	87.4	60.3				174.6
Total	1.8	554.5	942.6	438.5	4.7	2.7	0.0	1,944.8
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	75.0	377.7	879.1	896.0				2,227.8
Mass.	5.9	8.1	24.7	9.4				48.1
N.H.	17.3	53.5	175.3	43.7				289.8
Total	98.2	439.3	1,079.1	949.1				2,565.7
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	133.0	585.1	814.0	323.1	110.7			1,965.9
Mass.	5.3	6.7	6.4	6.3				24.8
N.H.	3.4	27.9	8.7	43.8	6.5			90.2
Total	141.7	619.7	829.1	373.2	117.2			2,080.9
***2007** Season, 151 days, Dec 1 - Apr 30								
Maine	574.6	1,208.4	1,392.7	443.4	146.0	0.4	0.1	3,765.6
Mass.	2.2	0.4	4.4	3.4				10.3
N.H.	44.8	141.5	78.9	12.9	12.1			290.2
Total	621.6	1,350.3	1,476.0	459.7	158.0	0.4		4,066.1
***2008** Season, 152 days, Dec 1 - Apr 30								
Maine	392.6	986.0	1,970.1	962.6	47.3			4,358.6
Mass.	4.3	3.2	7.9	10.4				25.8
N.H.	94.2	112.3	156.6	34.5	1.7			399.2
Total	491.1	1,101.5	2,134.6	1,007.4	49.0			4,783.5

* Preliminary data

Table 3. Distribution of landings (metric tons) in the Maine northern shrimp fishery by gear type and month, 2001 - 2008.

2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May									
Trawl			532.8	360.6	31.4	26.4	0.3	951.5	89%
Trap			43.2	72.9	5.7	0.1	0	121.9	11%
Total			576.0	433.5	37.1	26.5	0.3	1,073.4	
2002 Season, 25 days, Feb 15 - Mar 11									
Trawl				245.3	70.1		2.5	318.0	87%
Trap				40.2	6.6		0	46.8	13%
Total				285.5	76.7		2.5	364.8	
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off									
Trawl			411.3	465.6	1.2		0.02	878.1	81%
Trap			66.2	136.9	0		0	203.1	19%
Total			477.5	602.4	1.2		0.02	1,081.2	
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off									
Trawl	1.79	510.33	806.11	360.14	4.68	2.70	0.03	1685.76	96%
Trap	0.00	11.95	38.96	15.99				66.90	4%
Total	1.79	522.29	845.07	376.13	4.68	2.70	0.03	1752.67	
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off									
Trawl	74.99	369.13	750.59	637.23				1831.94	82%
Trap	0.00	8.58	128.53	258.78				395.89	18%
Total	74.99	377.70	879.12	896.01				2227.82	
2006 Season, 140 days, Dec 12 - Apr 30									
Trawl	132.8	568.5	652.6	230.0	110.1			1694.1	86%
Trap	0.1	16.6	161.3	93.2	0.6			271.8	14%
Total	133.0	585.1	814.0	323.1	110.7			1965.9	
***2007** Season, 151 days, Dec 1 - Apr 30									
Trawl	570.95	1,171.42	1,073.20	323.91	135.31	0.37	0.10	3,275.25	87%
Trap	3.64	36.99	319.52	119.52	10.64			490.31	13%
Total	574.59	1,208.41	1,392.72	443.42	145.95	0.37	0.10	3,765.57	
***2008** Season, 152 days, Dec 1 - Apr 30									
Trawl	392.54	925.14	1,632.67	589.94	40.72			3,581.02	82%
Trap	0.10	60.84	337.38	372.64	6.59			777.54	18%
Total	392.65	985.98	1,970.06	962.57	47.31	0.00		4,358.56	

* Preliminary data

Table 4. Distribution of fishing effort (number of trawl trips) in the Gulf of Maine northern shrimp fishery by state and month, 1987 – 2008.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1987 Season, 182 days, Dec 1 - May 31								
Maine	993	2,373	3,073	2,241	617	340	16	9,653
Mass.	325	354	414	426	283	317	164	2,283
N.H.	67	164	175	95	28		32	561
Total	1,385	2,891	3,662	2,762	928	657		12,285
1988 Season, 183 days, Dec 1 - May 31								
Maine	972	2,183	2,720	1,231	193	122		7,421
Mass.	28	326	426	315	26	57		1,178
N.H.	72	231	236	99	3			641
Total	1,072	2,740	3,382	1,645	222	179		9,240
1989 Season, 182 days, Dec 1 - May 31								
Maine	958	2,479	2,332	936	249	84		7,038
Mass.	103	479	402	254	297	102		1,637
N.H.	120	369	312	69	16			886
Total	1,181	3,327	3,046	1,259	562	186		9,561
1990 Season, 182 days, Dec 1 - May 31								
Maine	1,036	1,710	1,529	1,986	897	238		7,396
Mass.	147	459	273	202	175	118		1,374
N.H.	178	363	284	157	6			988
Total	1,361	2,532	2,086	2,345	1,078	356		9,758
1991 Season, 182 days, Dec 1 - May 31								
Maine	568	1,286	2,070	1,050	438	139		5,551
Mass.	264	416	401	231	154	147		1,613
N.H.	279	285	135	82	22	1		804
Total	1,111	1,987	2,606	1,363	614	287		7,968
1992 Season, 153 days, Dec 15 - May 15								
Maine	411	1,966	2,700	1,222	318	141		6,758
Mass.	59	337	145	101	41			683
N.H.	96	153	76	29	3			357
Total	566	2,456	2,921	1,352	362	141		7,798
1993 Season, 138 days, Dec 14 - April 30								
Maine	249	1,102	1,777	1,032	227			4,387
Mass.	60	200	250	185	72			767
N.H.	76	246	275	256	151			1,004
Total	385	1,548	2,302	1,473	450			6,158
1994 Season, 122 days, Dec 15 - Apr 15								
Maine	265	1,340	1,889	1,065	122			4,681
Mass.	58	152	147	83	15			455
N.H.	169	228	266	173	18			854
Total	492	1,720	2,302	1,321	155			5,990
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	879	2,341	2,641	1,337	694			7,892
Mass.	145	385	275	157	109			1,071
N.H.	189	331	279	359	344			1,502
Total	1,213	3,057	3,195	1,853	1,147			10,465
1996 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	1,341	2,030	3,190	1,461	444	457		8,923
Mass.	299	248	325	269	106	126		1,373
N.H.	331	311	389	248	155	61		1,495
Total	1,971	2,589	3,904	1,978	705	644		11,791
1997 Season, 156 days, Dec 1- May 31, two 5-day and four 4-day blocks off								
Maine	1,674	1,753	2,737	1,178	793	530		8,665
Mass.	184	226	245	114	7	1		777
N.H.	277	245	301	218	189	62		1,292
Total	2,135	2,224	3,283	1,510	989	593		10,734
1998 Season, 105 days, Dec 8-May 22, weekends off except Mar 14-15, Dec 25-31 and Mar 16-31 off.								
Maine	852	1,548	1,653	725	346	189		5,313
Mass.	94	200	148	70	3	1		515
N.H.	141	216	182	134	83	22		778
Total	1,086	1,964	1,983	929	432	212		6,606
1999 Season, 90 days, Dec 15 - May 25, weekends, Dec 24 - Jan 3, Jan 27-31, Feb 24-28, Mar 16-31, and Apr 29 - May 2 off.								
Maine	190	556	1,125	553	324	172		2,920
Mass.	39	57	71	9	40			216
N.H.	82	192	213	44	123	21		675
Total	311	805	1,409	606	487	193		3,811
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		653	1,838	401				2,892
Mass.		23	100	27				150
N.H.		36	179	78				293
Total		712	2,117	506				3,335
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 15 off, experimental offshore fishery in May								
Maine		1,531	1,230	116	39	6		2,922
Mass.		111	47	11	1			170
N.H.		305	145	27	30			507
Total		1,947	1,422	154	70	6		3,599
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			573	221			14	808
Mass.			13	9			1	22
N.H.			126	53				179
Total			712	283			15	1,010

Table 4 continued.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		773	1,020				49	1,842
Mass.		35	39					74
N.H.		82	159					241
Total		890	1,218				49	2,157
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	7	563	883	337	13	14	3	1,820
Mass.		9	31	8				48
N.H.		46	139	65				250
Total	7	618	1,053	410	13	14	3	2,118
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	141	647	920	760				2,468
Mass.	12	18	49	23				102
N.H.	24	76	216	76				392
Total	177	741	1,185	859				2,962
2006 Season, 140 days, Dec 12 - Apr 30								
Maine	131	426	515	246	82			1,400
Mass.	10	12	14	12				48
N.H.	5	23	19	52	10			109
Total	146	461	548	310	92			1,557
***2007** Season, 151 days, Dec 1 - Apr 30								
Maine	343	790	796	319	114	1	12	2,375
Mass.	3	1	8	7				19
N.H.	24	79	65	16	27			211
Total	370	870	869	342	141	1	12	2,605
***2008** Season, 152 days, Dec 1 - Apr 30								
Maine	397	984	1,337	636	48			3,402
Mass.	8	9	8	9				34
N.H.	63	130	120	31	5			349
Total	468	1,123	1,465	676	53			3,785

* Preliminary data

Table 5. Distribution of fishing trips in the Maine northern shrimp fishery by gear type and month, 2001 – 2008.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	% of total
2001									
Trawl		1,531	1,230	116	39	6		2,922	83%
Trap		191	347	68	1			607	17%
Total		1,722	1,577	184	40	6		3,529	
2002									
Trawl			573	221			14	808	77%
Trap			193	55				248	23%
Total			766	276			14	1,056	
2003									
Trawl		773	1,020				49	1,842	72%
Trap		253	466					719	28%
Total		1,026	1,486					2,561	
2004									
Trawl	7	563	883	337	13	14	3	1,820	83%
Trap	0	75	210	90				375	17%
Total	7	638	1,093	427	13	14	3	2,195	
2005									
Trawl	141	647	920	760				2,468	75%
Trap		20	352	469				841	25%
Total	141	667	1,272	1,229				3,309	
2006									
Trawl	131	426	515	246	82			1,400	66%
Trap	3	90	375	257	12			737	34%
Total	134	516	890	503	94			2,137	
***2007**									
Trawl	343	790	796	319	114	1	12	2,375	69%
Trap	9	126	581	320	17			1,053	31%
Total	352	916	1,377	639	131	1	12	3,428	
***2008**									
Trawl	397	984	1,337	636	48			3,402	69%
Trap	4	220	654	594	47	1		1,520	31%
Total	401	1,204	1,991	1,230	95	1		4,922	

* preliminary data

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

Season	Maine	Massachusetts	New Hampshire	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	235	25	28	288
2002	167	8	23	198
2003	213	12	23	248
2004	169	7	15	191
2005	167	9	22	198
2006	126	5	11	142
*2007	176	3	15	194
*2008	211	5	14	230

* preliminary

Table 7. Gulf of Maine northern shrimp trawl catch rates for 1991 – 2008. Mean CPUE in lbs/hour towed is from Maine port sampling. Mean catch in lbs/trip is from NMFS weighout and logbook data for trawl catches for all states.

Season	Maine pounds per hour towing			Pounds/trip
	Inshore (<55F)	Offshore (>55F)	Combined	
1991	94	152	140	988
1992	132	93	117	974
1993	82	129	92	767
1994	139	149	141	1,073
1995	172	205	193	1,362
1996	340	203	251	1,714
1997	206	192	194	1,454
1998	158	151	154	1,317
1999	148	147	147	1,067
2000	279	224	272	1,444
2001	100	135	109	740
2002	223	91	194	831
2003	174	215	182	1,029
2004	361	310	351	1,955
2005	235	212	228	1,615
2006	572	345	499	2,562
*2007	531	477	507	3,106
*2008	350	327	343	2,278

* Pounds/trip are preliminary

Table 8. Stratified retransformed mean weights per tow of northern shrimp collected during the Maine – New Hampshire inshore trawl surveys, 2003 – 2008, 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	**4.22**	40	3.46	5.11	**1.96**	33	1.39	2.66
2004	**3.98**	42	3.42	4.61	**1.56**	38	1.07	2.18
2005	**7.81**	40	6.61	9.21	**3.70**	25	2.56	5.21
2006	**11.17**	46	8.65	14.34	**2.10**	38	1.46	2.92
2007	**10.56**	43	7.79	14.21	**4.10**	45	3.23	5.16
***2008**	**14.79**	45	12.08	18.06				

*2008 data are preliminary.

Table 9. Stratified* mean numbers and weights per tow of northern shrimp collected during *R/V Gloria Michelle* state/federal summer surveys, 1984 - 2008.

		Log_e transformed				
Year	N Tows	Age-1.5 Number	>22 mm** Number	>22 mm** Weight (kg)	Total Number	Total Weight (kg)
1984		18	316	3.4	1,152	10.5
1985	44	332	1,169	11.5	1,825	17.7
1986	40	358	860	10.0	1,695	19.6
1987	41	342	854	9.5	1,533	15.4
1988	41	828	298	3.4	1,269	12.8
1989	43	276	564	6.1	1,884	17.0
1990	43	142	1,127	12.0	1,623	18.1
1991	43	482	657	8.0	1,256	11.7
1992	45	282	397	4.8	955	9.4
1993	46	757	250	2.8	1,157	9.1
1994	43	368	243	2.7	984	8.7
1995	35	292	628	7.0	1,449	13.3
1996	32	232	358	4.0	776	8.8
1997	40	374	245	2.8	762	7.7
1998	35	134	170	1.9	583	6.3
1999	42	114	174	1.9	398	5.8
2000	35	450	283	3.2	808	6.4
2001	36	18	146	1.5	451	4.3
2002	38	1,164	261	2.9	1,445	9.2
2003	37	11	173	1.7	564	5.5
2004	35	286	519	5.3	887	10.3
2005	46	1,752	871	10.3	3,661	23.4
2006	29	374	2,773	29.9	9,998	66.0
2007	43	28	412	4.1	887	11.5
2008	38	506	995	10.8	1,737	16.8
Mean	40	397	590	6.5	1,589	13.8
Median	41	332	397	4.1	1,157	10.5

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

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

Fishing Season	New Recruits (millions)	Fully-Recruited (millions)	F (NR+FR)	Biomass (1000 mt)	Exploitation Rate
1985	809	869	0.27	12.27	20%
1986	857	998	0.25	15.81	19%
1987	678	1,128	0.31	16.49	23%
1988	559	1,035	0.18	14.65	14%
1989	714	1,041	0.20	12.43	16%
1990	840	1,118	0.29	15.08	22%
1991	568	1,138	0.24	16.18	18%
1992	434	1,048	0.22	14.38	18%
1993	392	924	0.18	12.05	15%
1994	607	855	0.23	9.89	18%
1995	820	901	0.51	12.25	36%
1996	944	805	0.71	14.04	46%
1997	570	668	1.01	10.31	57%
1998	475	351	0.70	5.85	45%
1999	356	320	0.44	4.87	32%
2000	266	339	0.49	4.91	34%
2001	361	289	0.28	4.66	21%
2002	266	383	0.08	4.96	7%
2003	622	466	0.13	6.29	10%
2004	400	748	0.22	8.36	17%
2005	723	720	0.20	11.88	16%
2006	2,043	918	0.08	18.84	6%
2007	2,027	2,137	0.13	30.10	11%
2008	465	2,845	0.18	28.12	14%
2009	881	2,160		27.85	
Overall average			0.31	13.3	22%
1985-94 average			0.24	13.9	18%

Table 11. Summary of results from surplus production analysis, Gulf of Maine northern shrimp.

	Input					Results			
Survey Year	Fall (kg/tow)	Maine (kg/tow)	Summer (kg/tow)	Spring ME/NH (kg/tow)	Catch (mt)	Biomass (mt)	F	B/Bmsy	F/Fmsy
1968	3.20	45.80			5,708	34.61	0.16	0.82	0.88
1969	2.70	31.20			12,136	36.41	0.36	0.86	1.96
1970	3.70	40.80			11,330	31.68	0.39	0.75	2.11
1971	3.00	9.40			10,594	27.34	0.42	0.65	2.31
1972	3.30	7.00			11,224	23.19	0.56	0.55	3.05
1973	1.90	7.80			9,691	17.56	0.66	0.42	3.60
1974	0.80	4.90			8,024	12.31	0.83	0.29	4.57
1975	0.90	6.70			6,142	7.39	1.29	0.17	7.04
1976	0.60	4.80			1,387	2.89	0.52	0.07	2.87
1977	0.20	1.60			372	2.44	0.14	0.06	0.75
1978	0.40	3.20			17	3.03	0.01	0.07	0.02
1979	0.50	4.40			487	4.27	0.10	0.10	0.55
1980	0.50	2.70			339	5.45	0.05	0.13	0.29
1981	1.50	3.00			1,071	7.24	0.13	0.17	0.73
1982	0.30	2.00			1,530	8.81	0.16	0.21	0.88
1983	1.00	4.20			1,397	10.38	0.12	0.25	0.67
1984	1.90		10.47		2,951	12.60	0.22	0.30	1.23
1985	1.60		17.69		4,131	13.70	0.30	0.32	1.65
1986	2.50		19.61		4,635	13.77	0.34	0.33	1.88
1987	1.70		15.40		5,253	13.28	0.42	0.31	2.29
1988	1.20		12.76		3,031	11.93	0.25	0.28	1.35
1989	1.81		16.95		3,315	12.74	0.25	0.30	1.39
1990	2.04		18.12		4,665	13.47	0.35	0.32	1.94
1991	0.95		11.68		3,571	12.86	0.27	0.30	1.50
1992	0.57		9.43		3,444	13.33	0.25	0.32	1.38
1993	1.86		9.14		2,143	14.08	0.14	0.33	0.77
1994	2.26		8.69		2,915	16.50	0.17	0.39	0.91
1995	1.64		13.29		6,466	18.66	0.36	0.44	1.97
1996	1.17		8.77		9,166	17.36	0.62	0.41	3.38
1997	1.35		7.73		7,079	12.66	0.66	0.30	3.63
1998	2.26		6.33		4,174	8.98	0.51	0.21	2.78
1999	2.39		5.78		1,816	7.52	0.23	0.18	1.26
2000	1.43		6.39		2,389	8.32	0.28	0.20	1.54
2001	0.63		4.33		1,329	8.73	0.14	0.21	0.76
2002	1.70		9.16		424	10.50	0.04	0.25	0.19
2003	1.08		5.45	4.22	1,211	13.86	0.08	0.33	0.43
2004	1.58		10.27	3.98	1,945	17.27	0.10	0.41	0.56
2005	2.77		23.38	7.81	2,566	20.68	0.12	0.49	0.63
2006	7.09		65.99	11.17	2,081	24.12	0.08	0.57	0.43
2007	5.54		11.51	10.56	4,066	28.65	0.14	0.68	0.74
2008	n/a		16.77	*14.79	4,784	31.65	0.15	0.75	0.80
2009						34.20		0.81	
Average	**1.84**		**13.80**		**4,171**	**15.39**	**0.30**		
					1971-74 average:	20.10	0.62		
	* preliminary data				1985-94 average:	13.57	0.27		
					2006-08 (3-yr) average:	28.14	0.12		

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

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

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

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

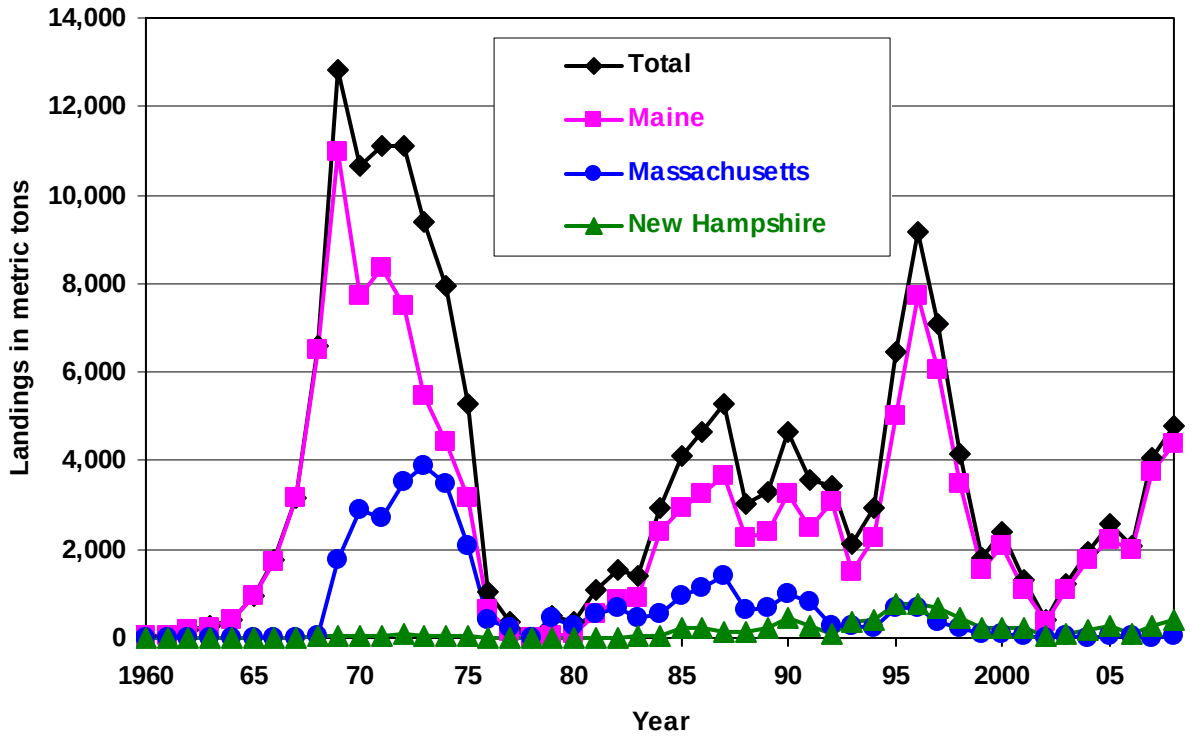


Figure 1. Gulf of Maine northern shrimp landings by year and state.

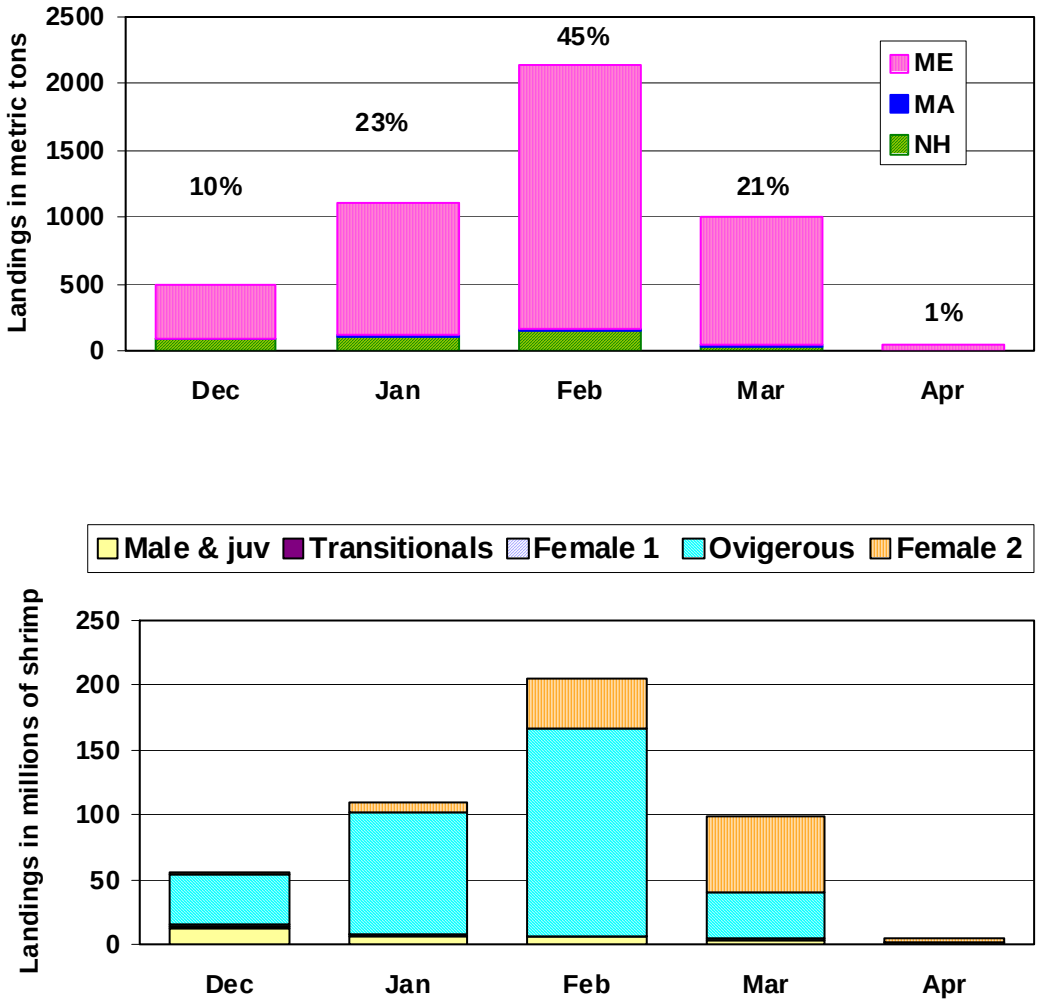


Figure 2. **Gulf of Maine northern shrimp landings by month in the 2008 season. Landings are in metric tons by state (above), and in millions of shrimp by development stage (below).**

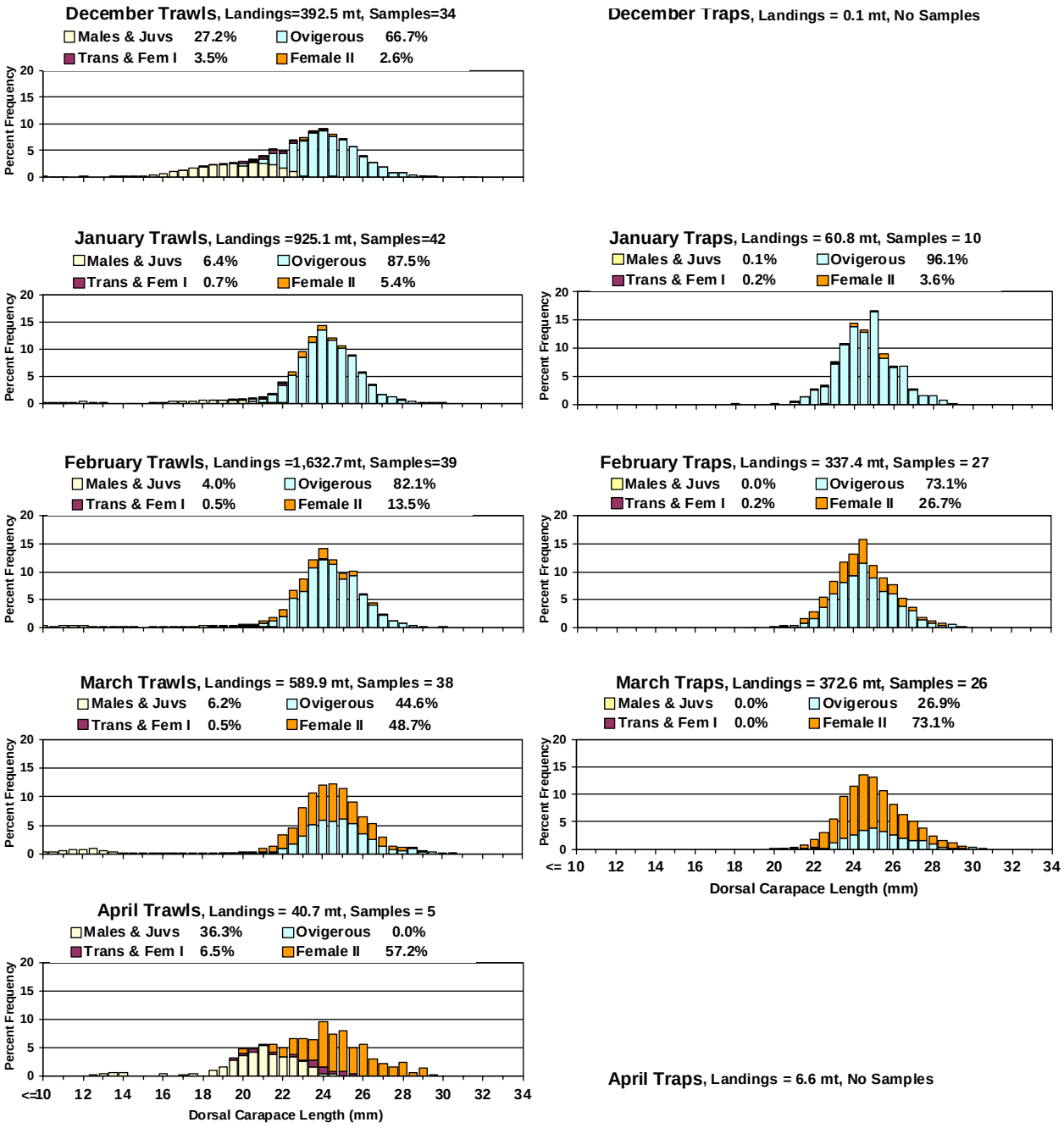


Figure 3. Relative length-frequency distributions from samples of Maine northern shrimp catches during the 2008 season by month, trawl catches on the left and trap catches on the right. Landings are preliminary.

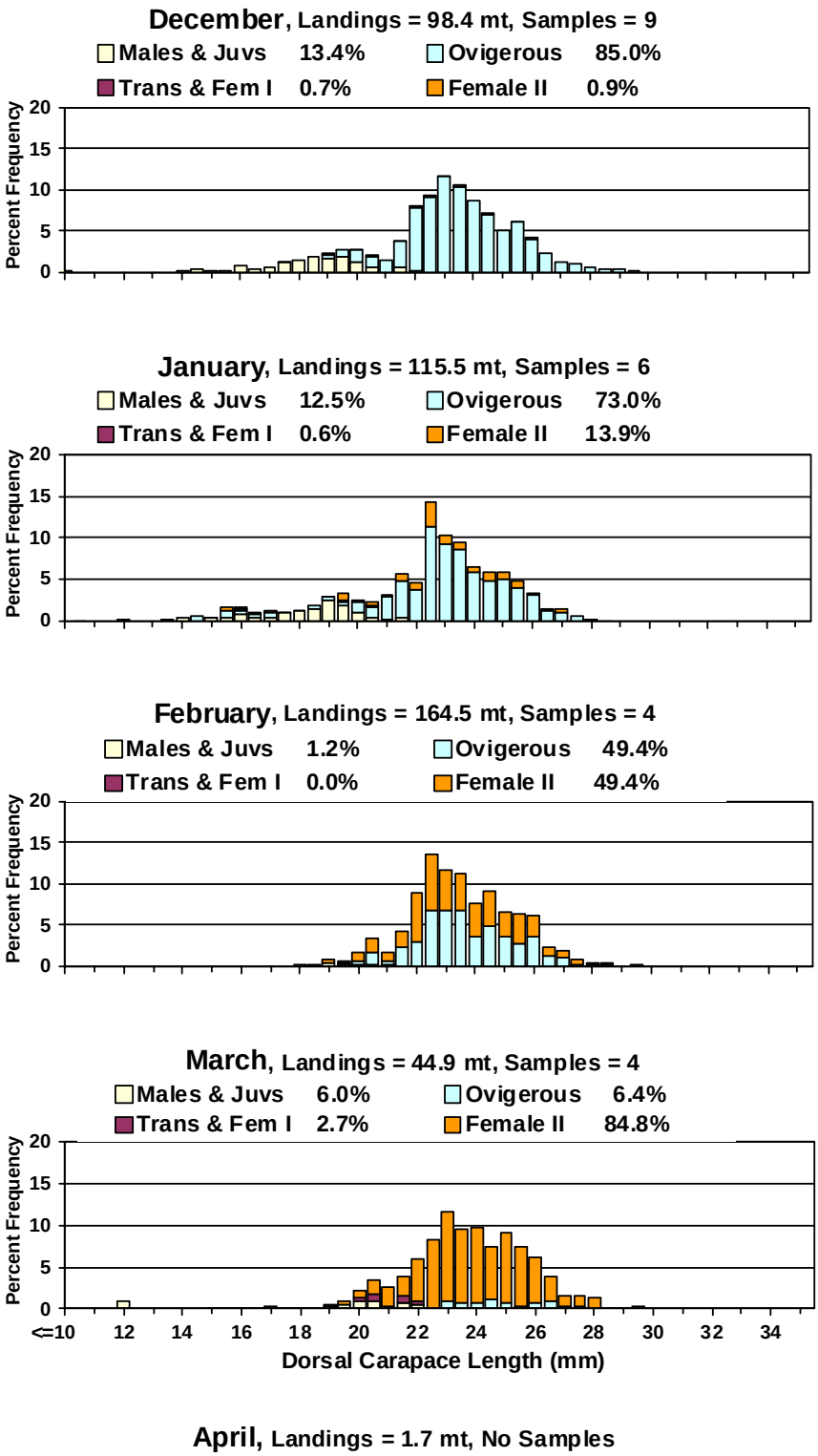


Figure 4. Relative length-frequency distributions from samples of Massachusetts and New Hampshire northern shrimp catches during the 2008 season by month. Landings are preliminary.

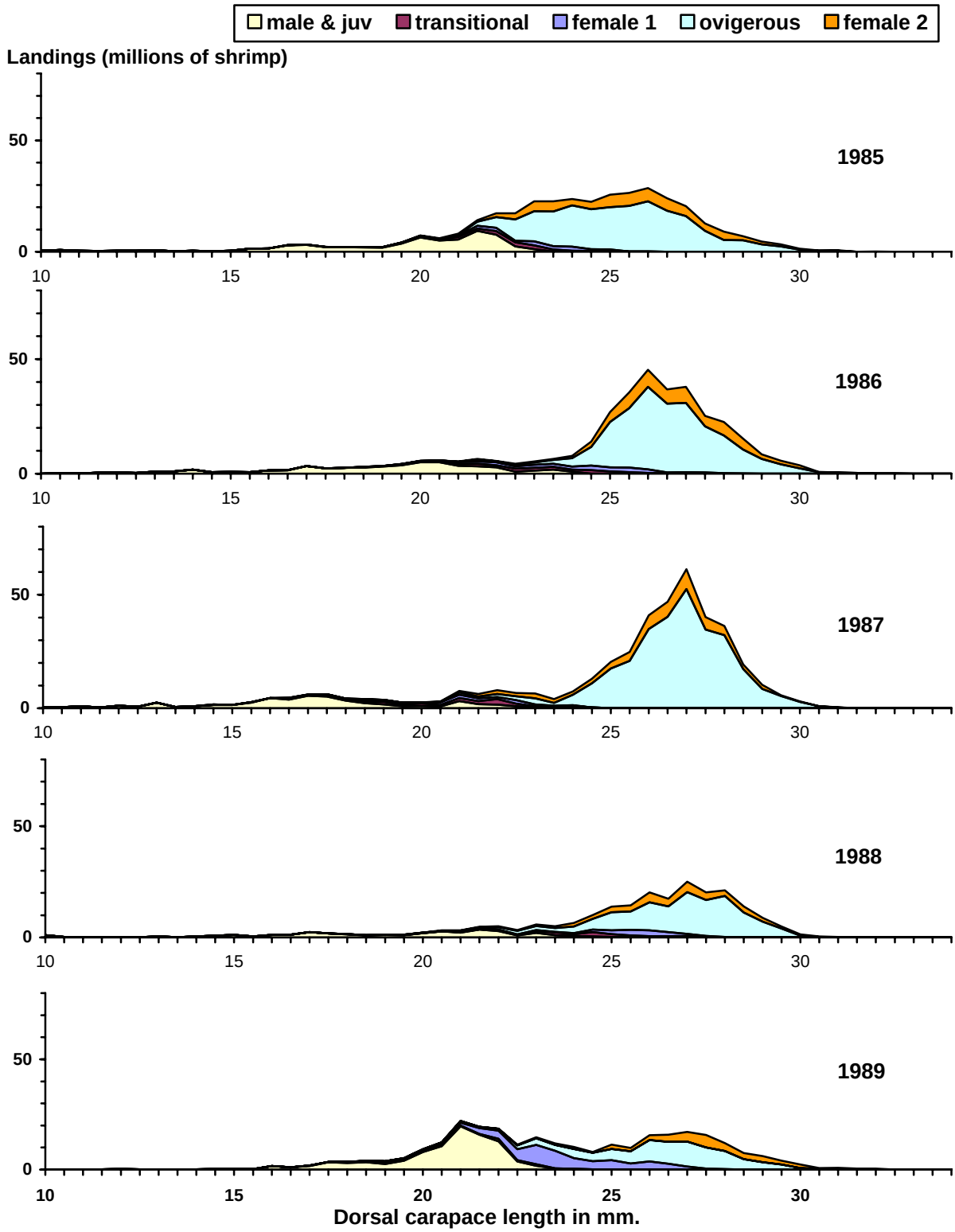


Figure 5. Gulf of Maine northern shrimp landings in estimated numbers of shrimp, by length, development stage, and fishing season. Landings are preliminary throughout.

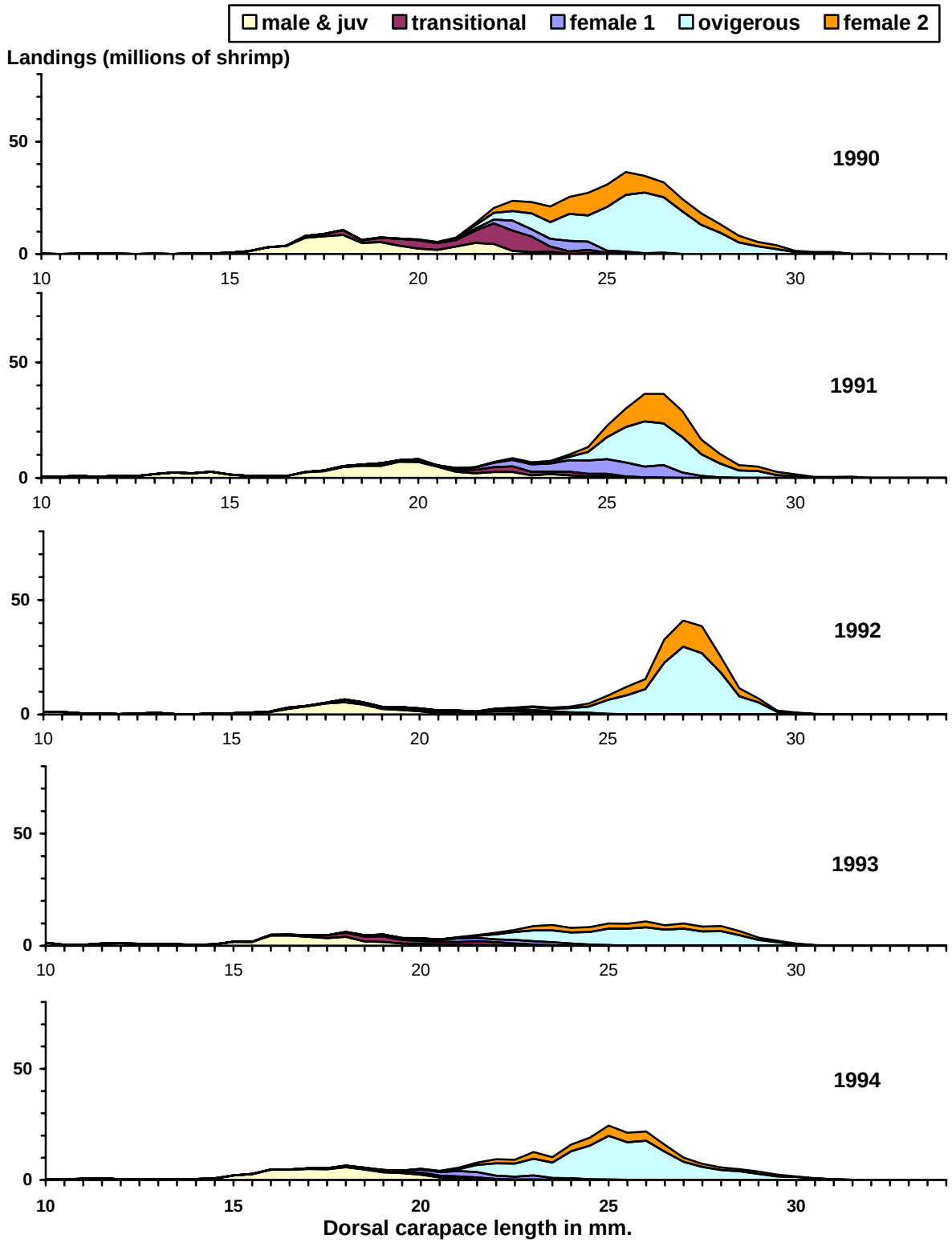


Figure 5 continued.

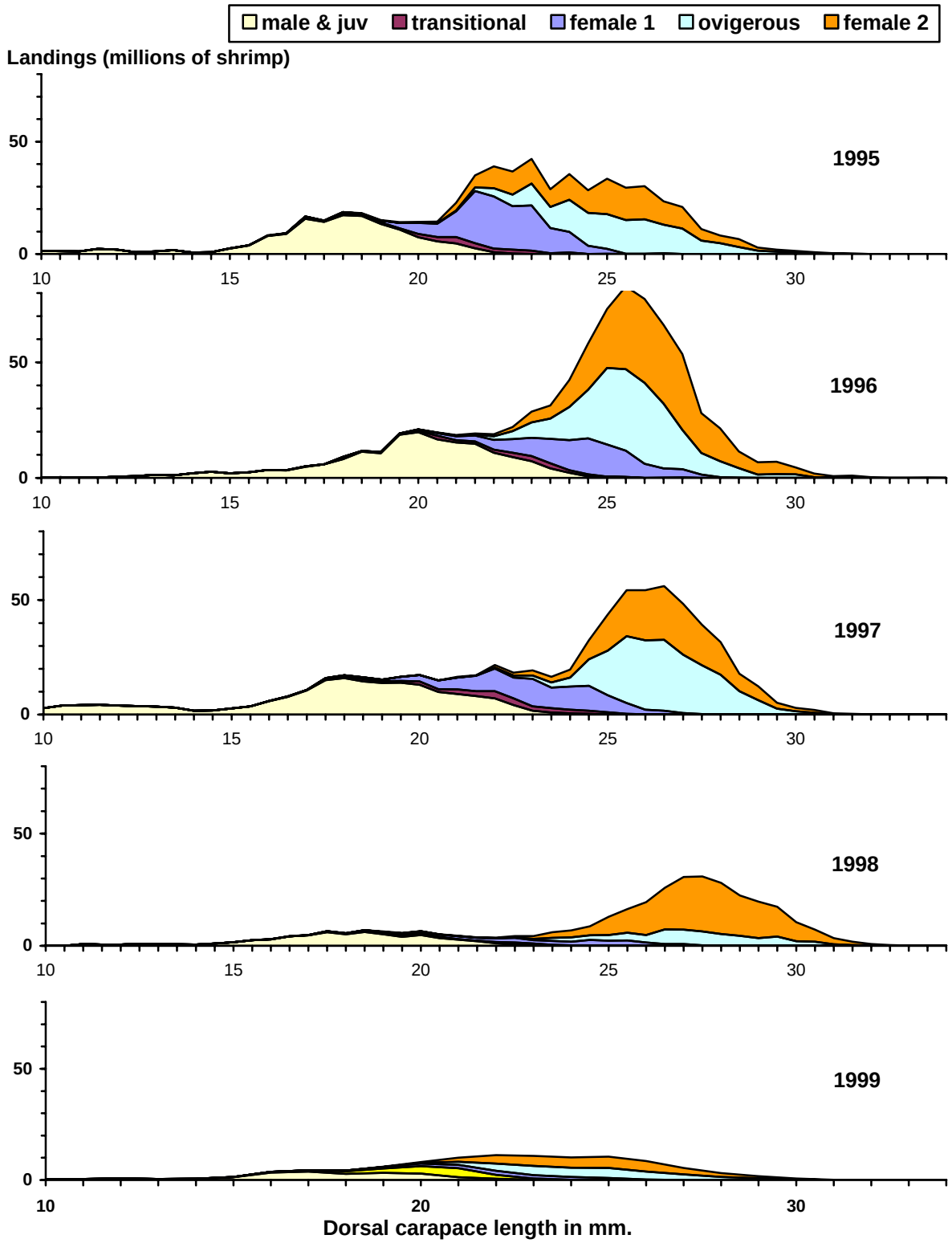
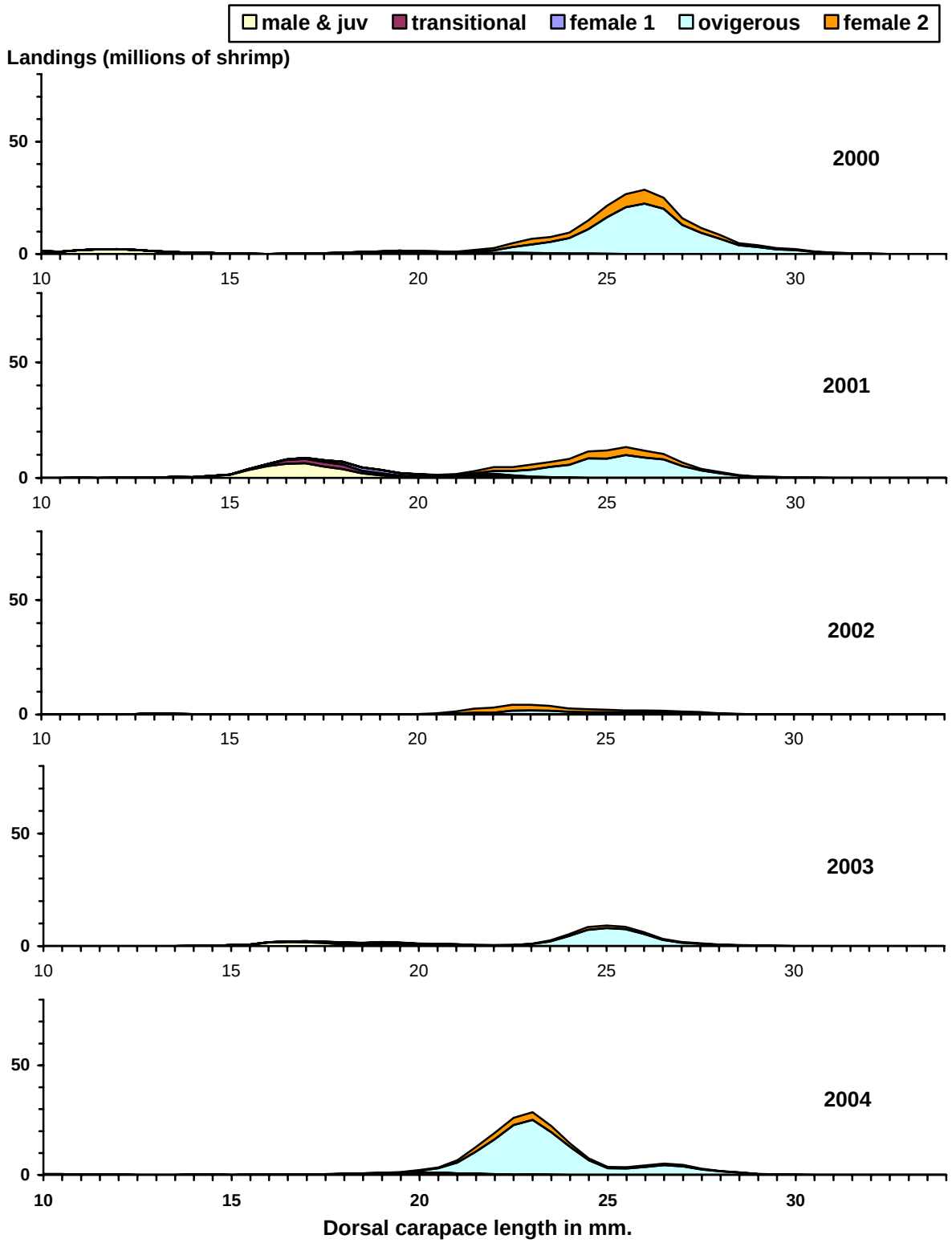


Figure 5 continued.



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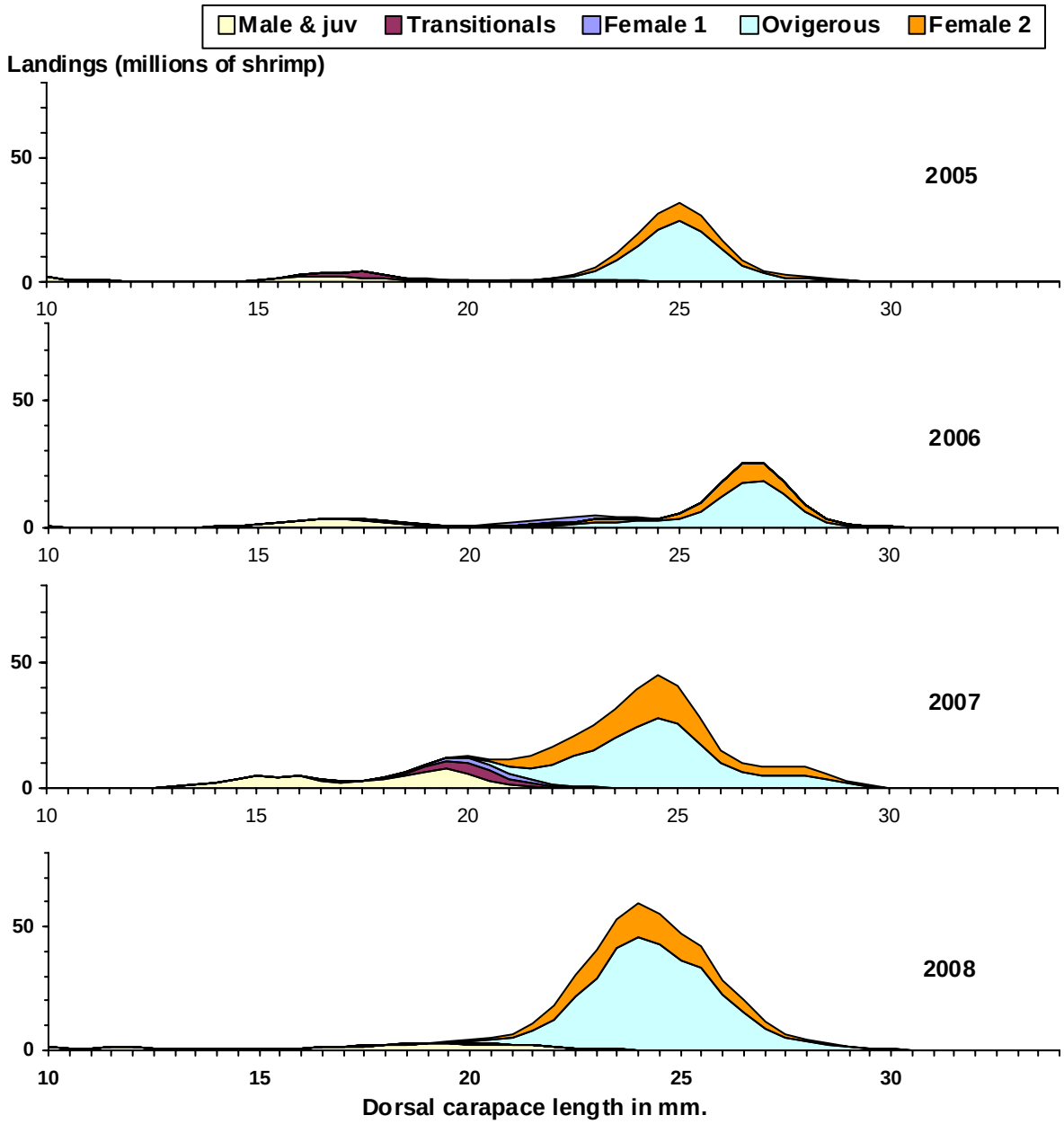

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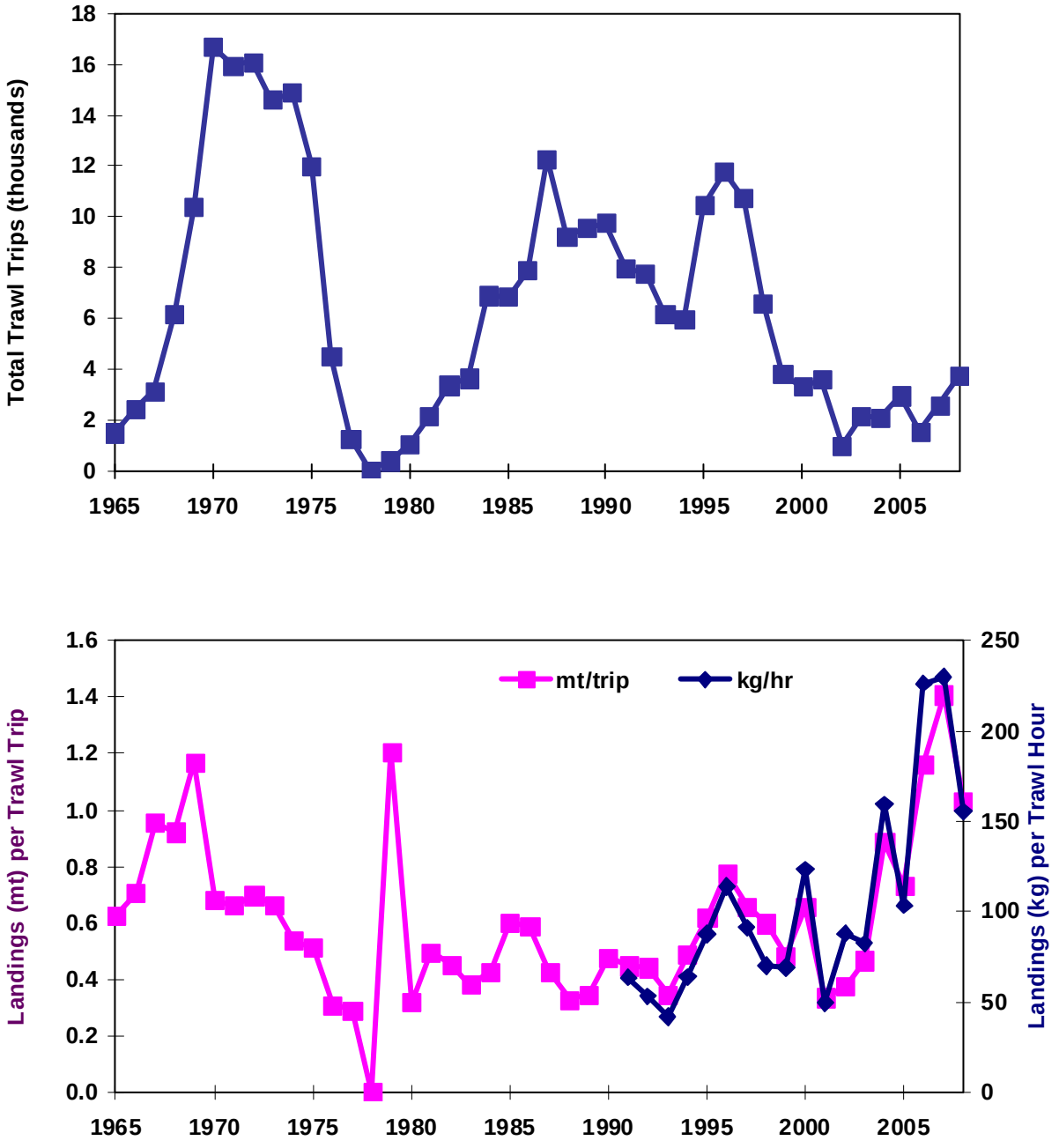
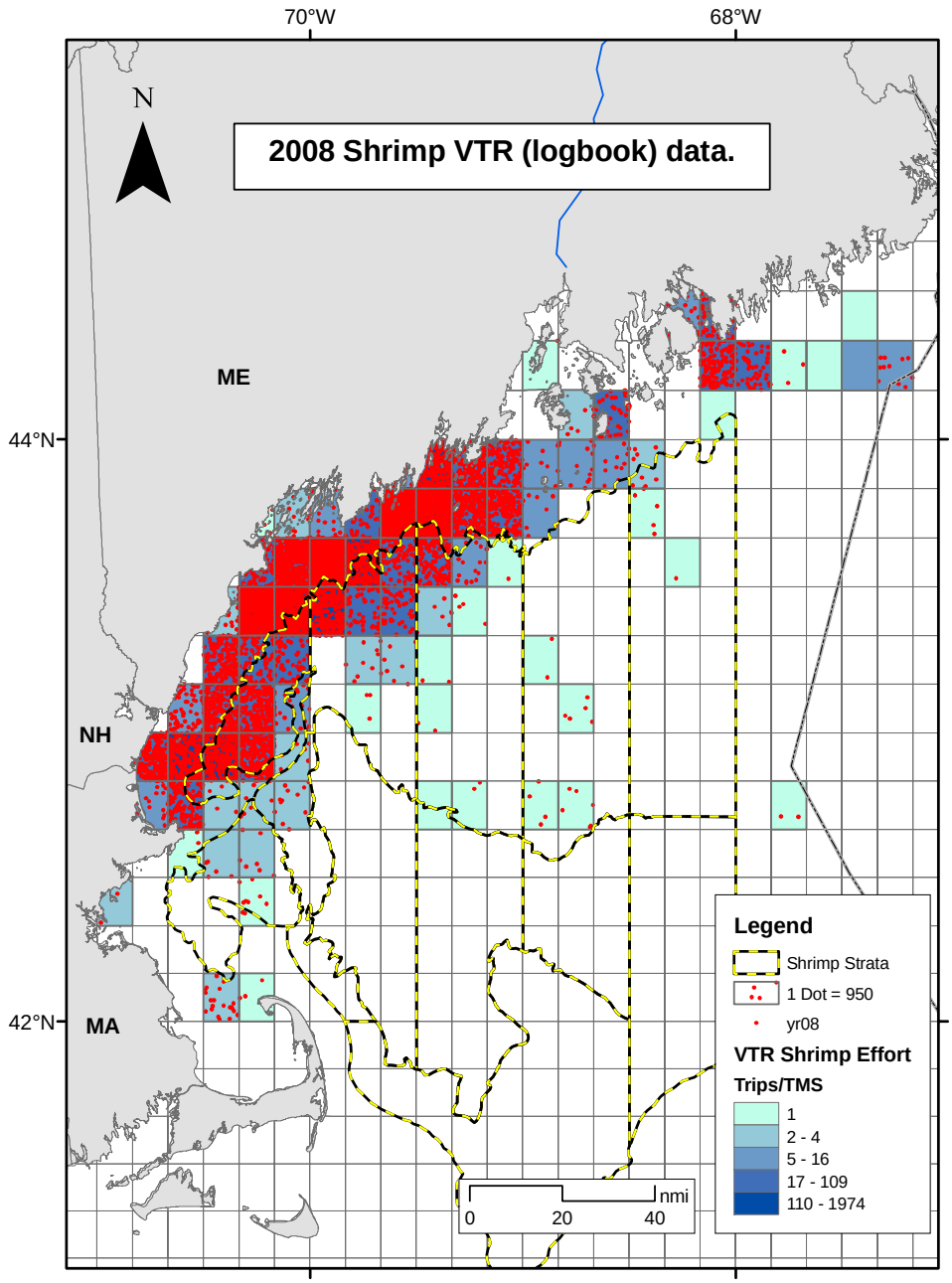


Figure 6. Nominal fishing effort (trawl trips) (above) and catch per unit effort (below), in the Gulf of Maine northern shrimp fishery by season. 2007 and 2008 data are preliminary.



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

Figure 7. Pounds caught and numbers of trips during the 2008 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 harvester logbook (VTR) data; does not include Maine non-federally-permitted vessel trips and catches.

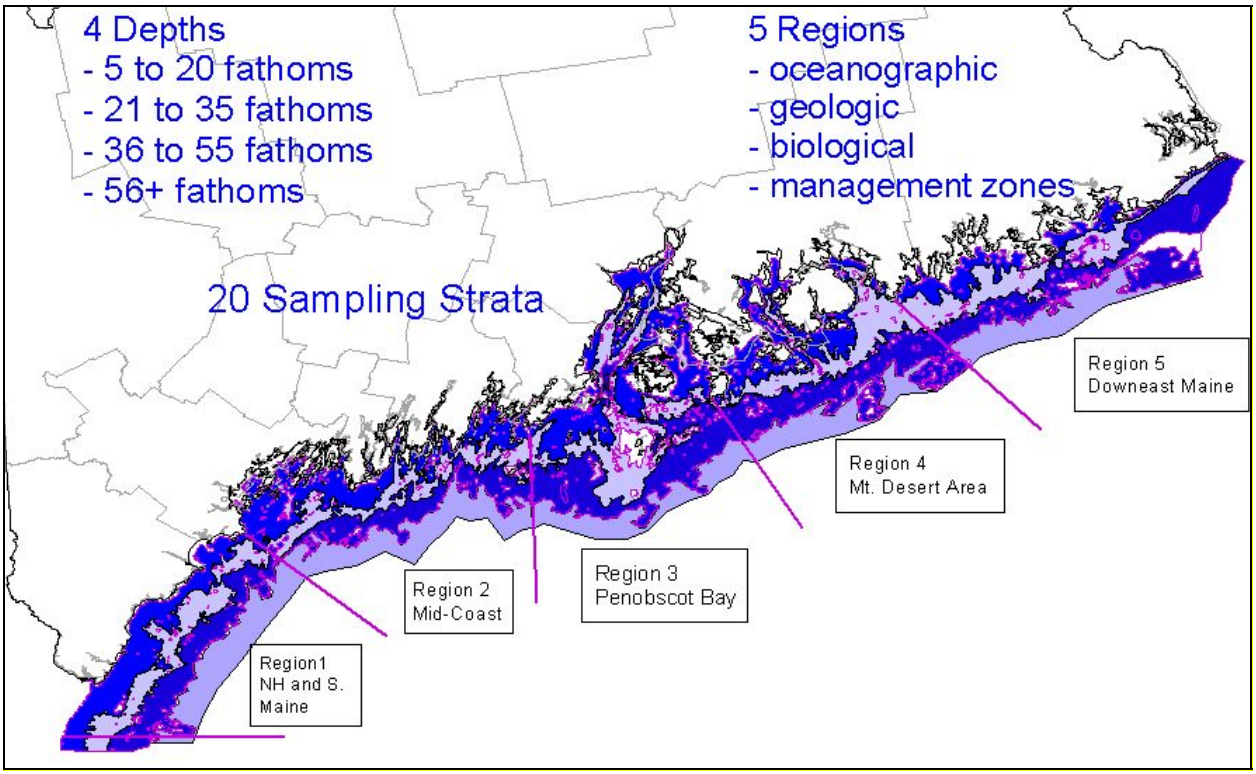
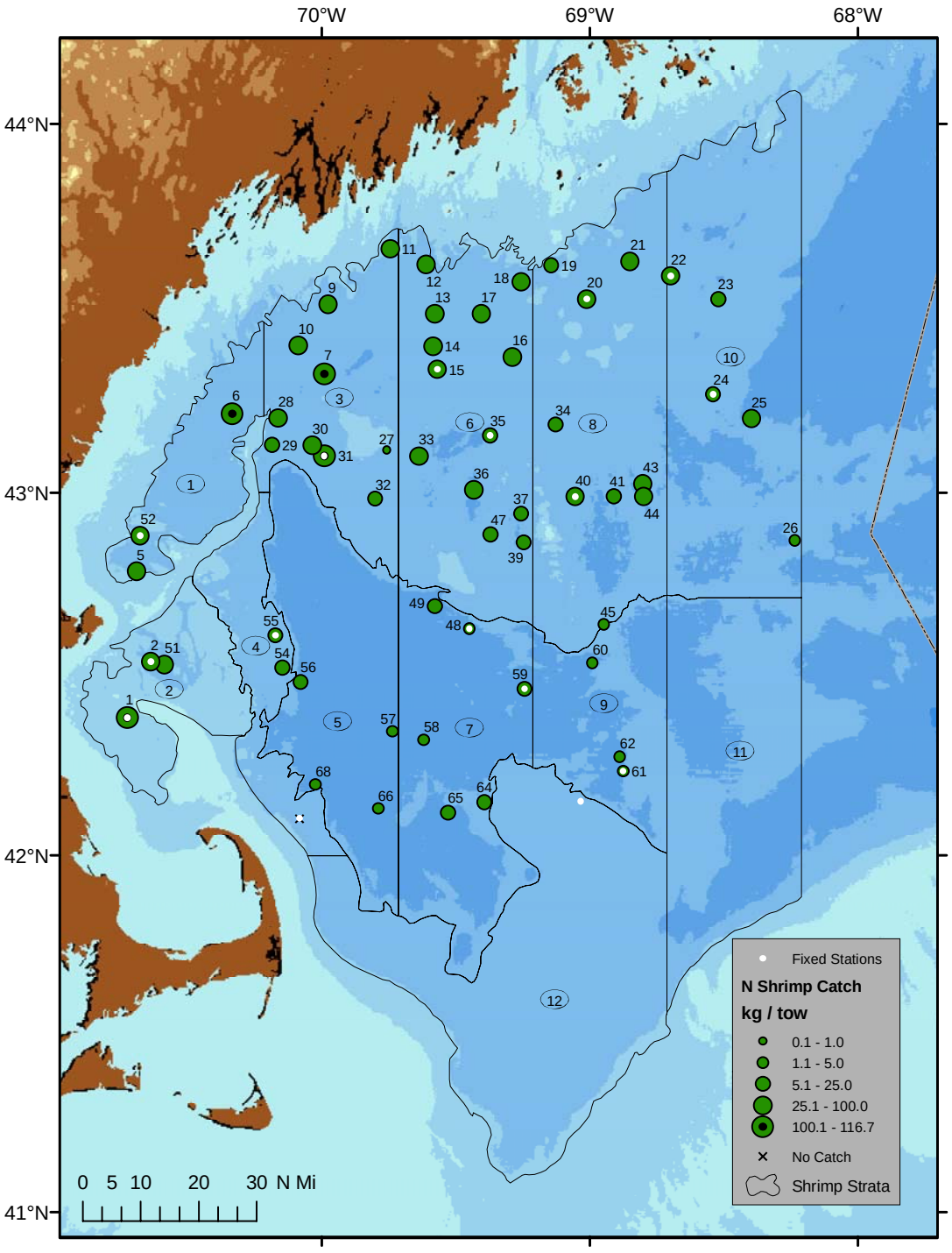
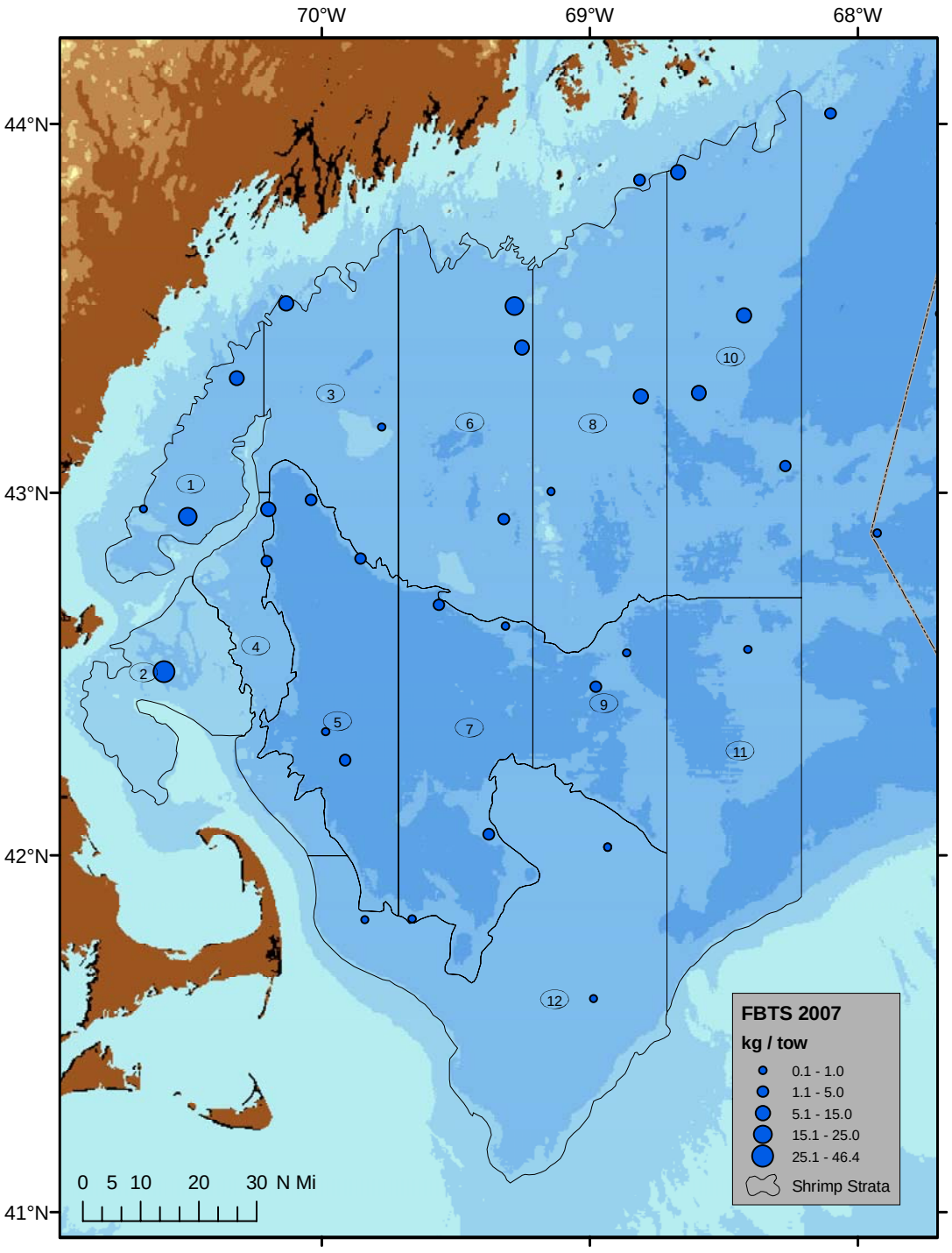


Figure 8a. Maine-New Hampshire inshore trawl survey depths and regions.



State/federal northern shrimp survey aboard the RF/V Gloria Michelle, statistical strata and survey sites with catches where successful tows were completed.

Figure 8b. State/federal northern shrimp survey aboard the R/V Gloria Michelle, July 20 – August 16, 2008; statistical strata and survey sites with catches (kg/tow).



Northern shrimp survey strata and observed distribution of catch per tow (kg) of northern shrimp collected during the 2007 Fall Bottom Trawl Survey in the western Gulf of Maine region aboard the R/V Albatross IV.

Figure 8c.

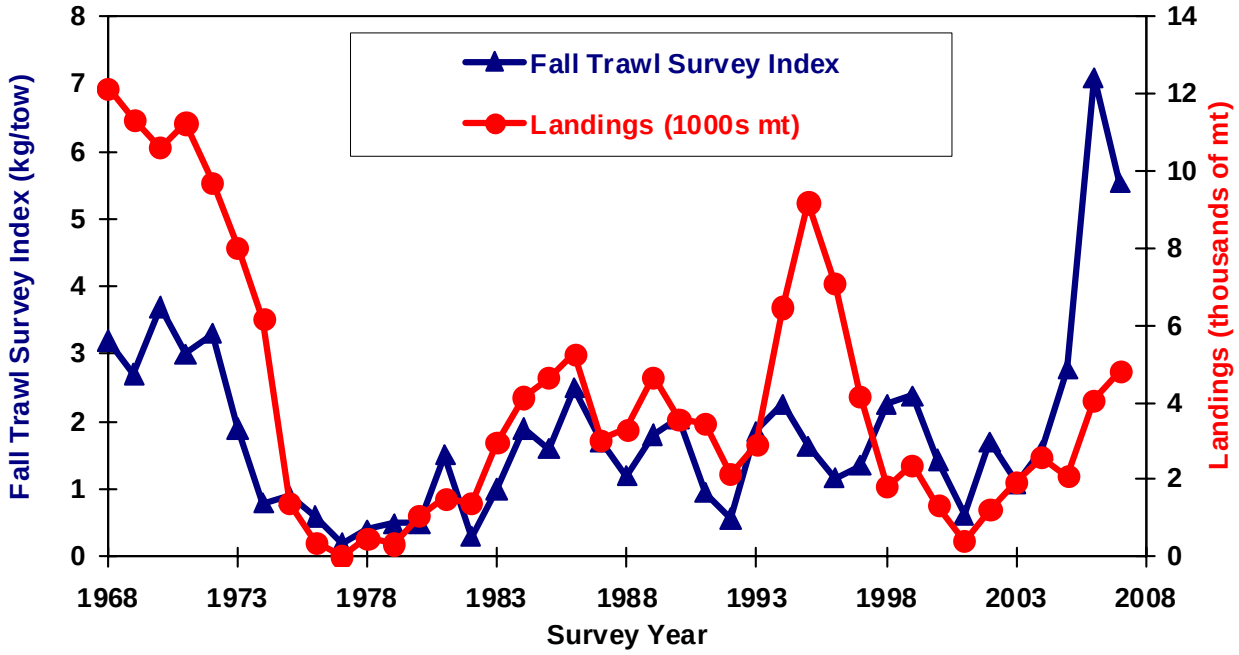
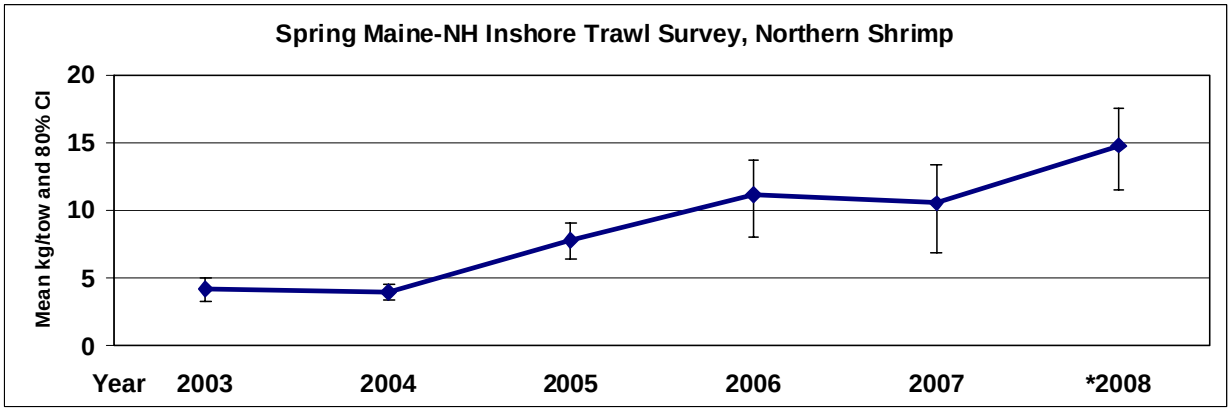


Figure 9. Fall trawl survey index and Gulf of Maine northern shrimp landings the following season.



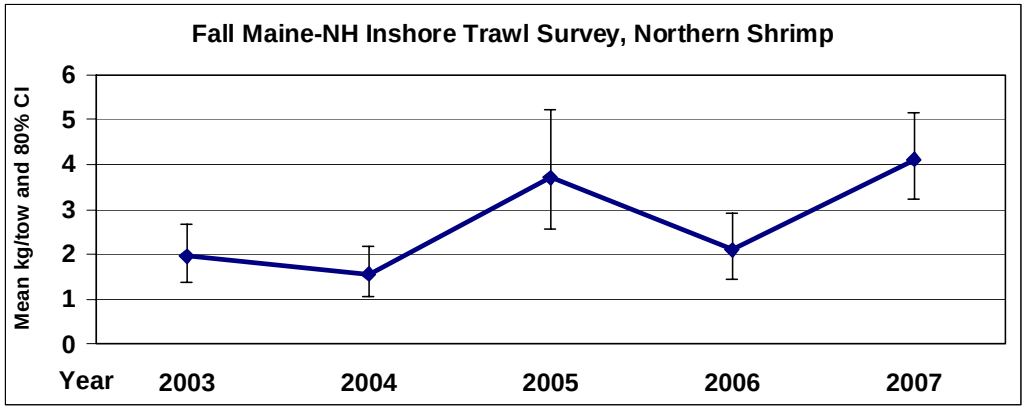


Figure 10. Maine-New Hampshire inshore trawl survey northern shrimp biomass indices, spring above and fall below.

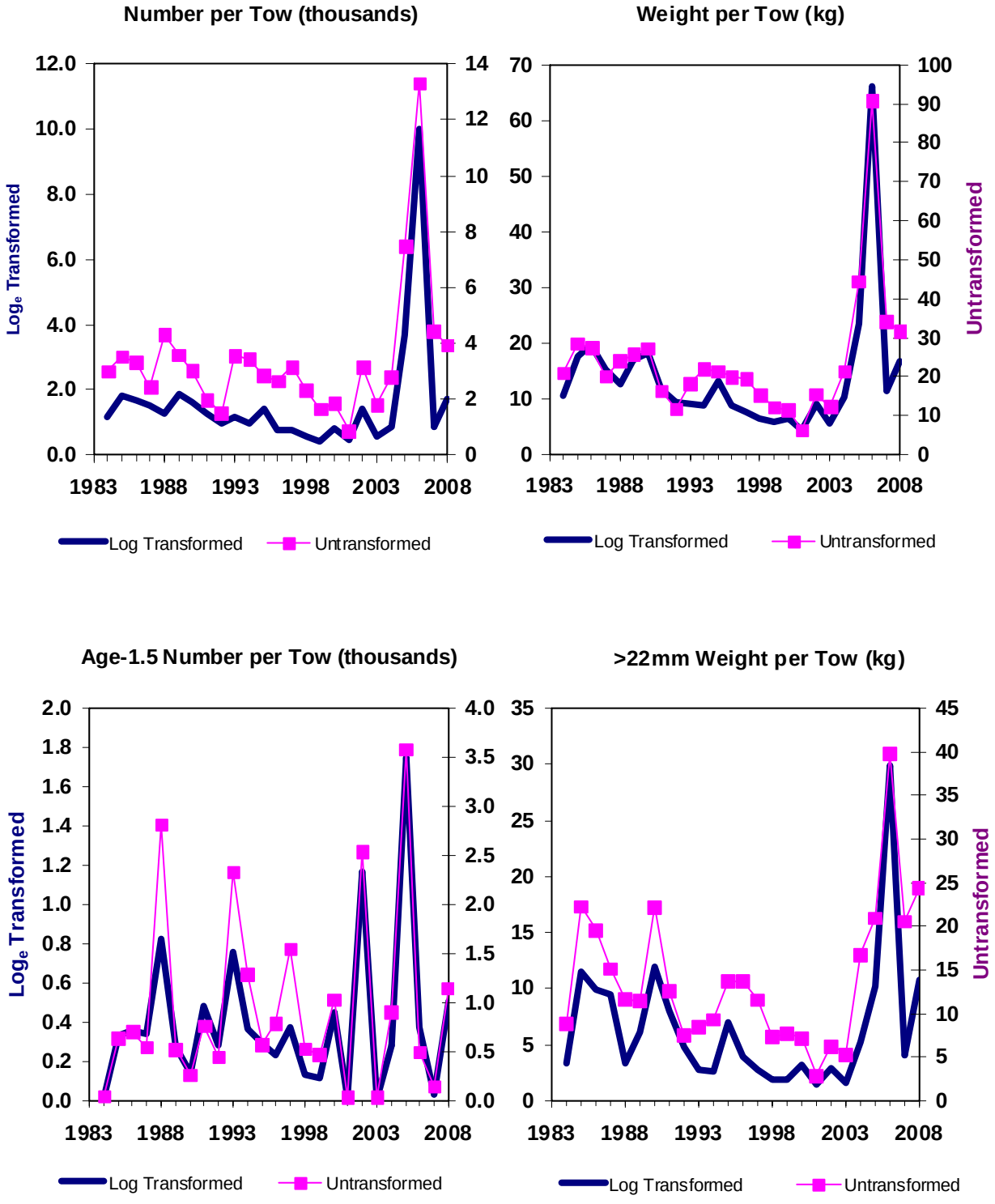


Figure 11. Gulf of Maine northern shrimp 2008 summer survey indices of abundance (left) and biomass (right), by survey year.

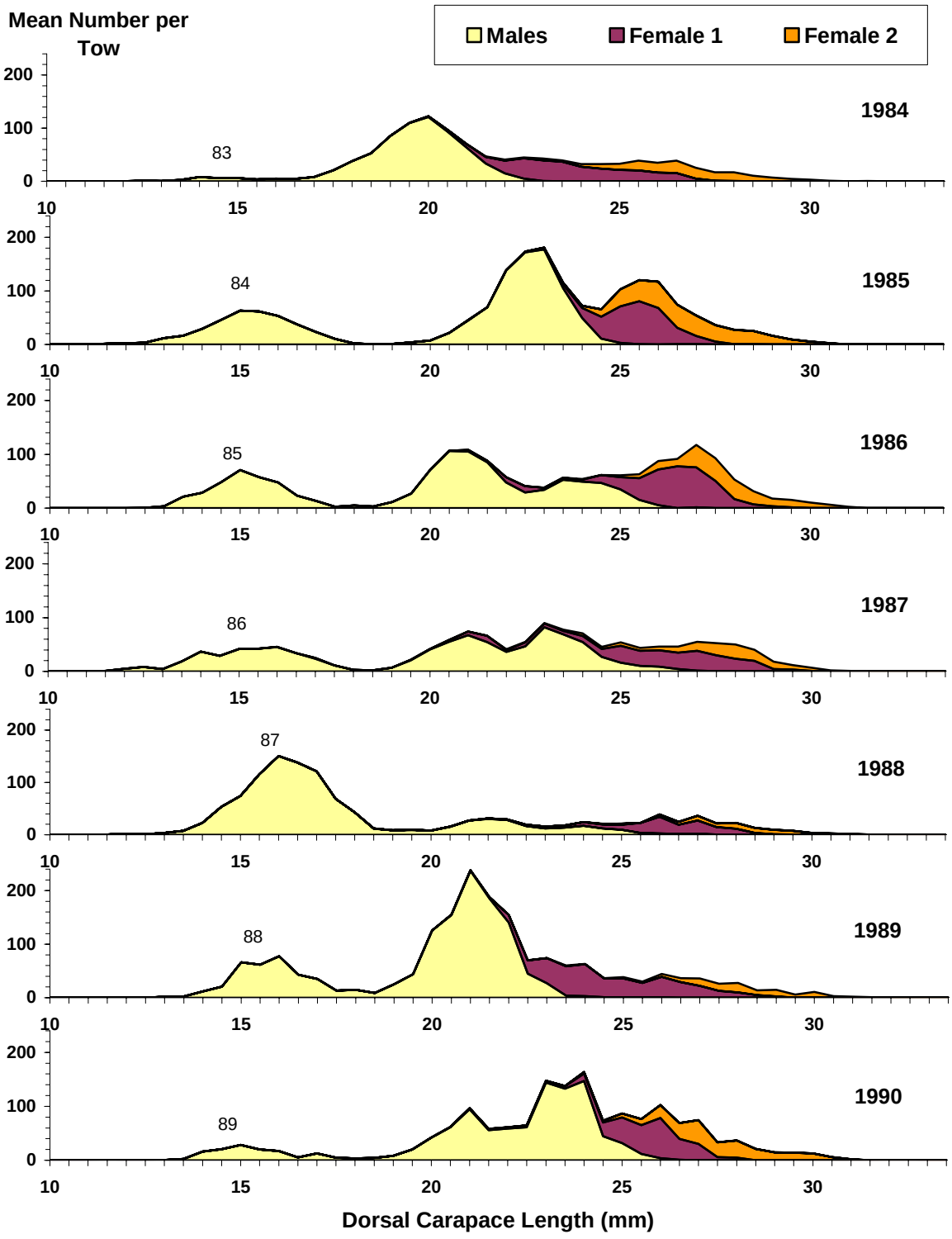


Figure 12. Gulf of Maine northern shrimp summer survey mean catch per tow by year, length, and development stage. Two-digit years are year class at assumed age 1.5.

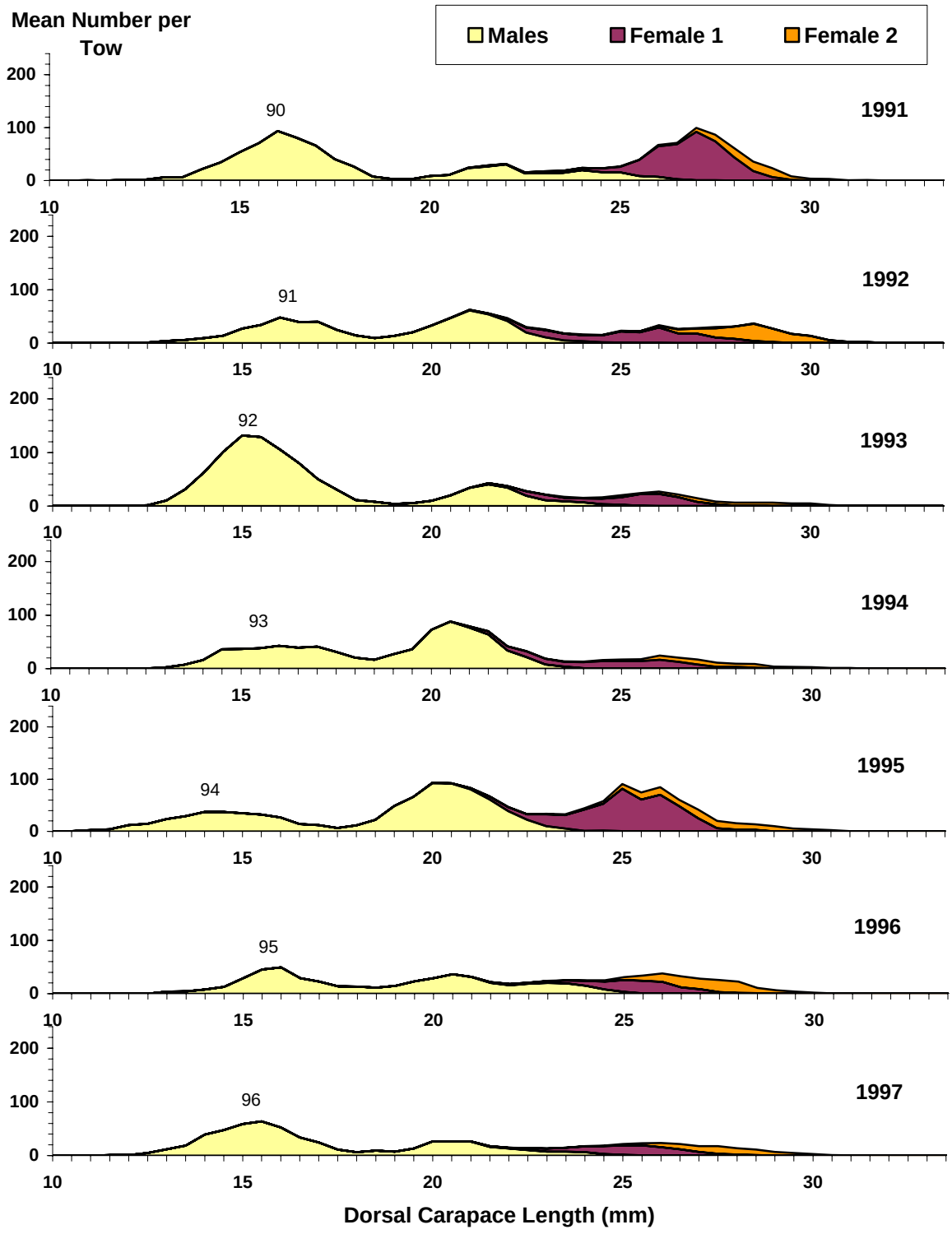


Figure 12 continued.

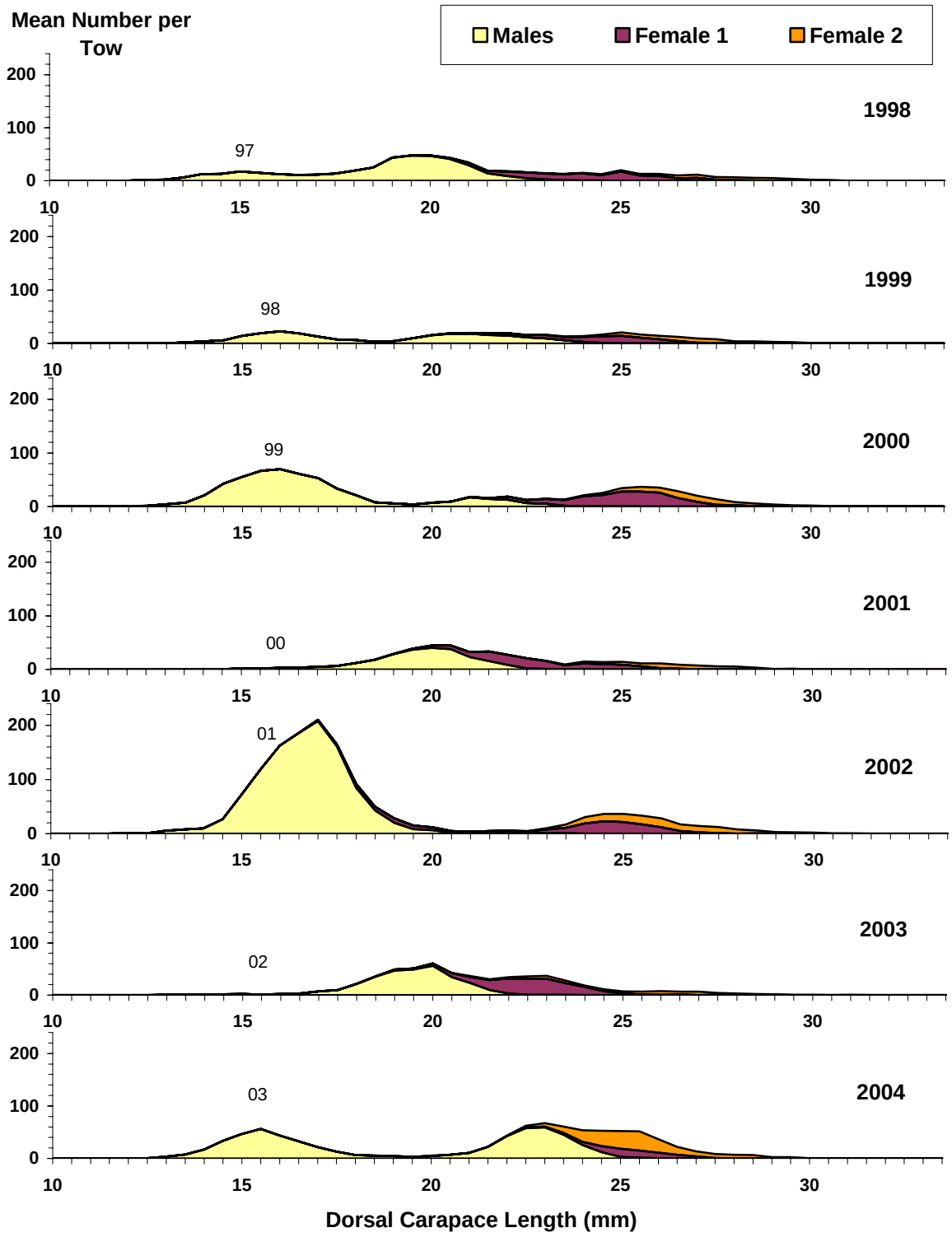


Figure 12 continued.

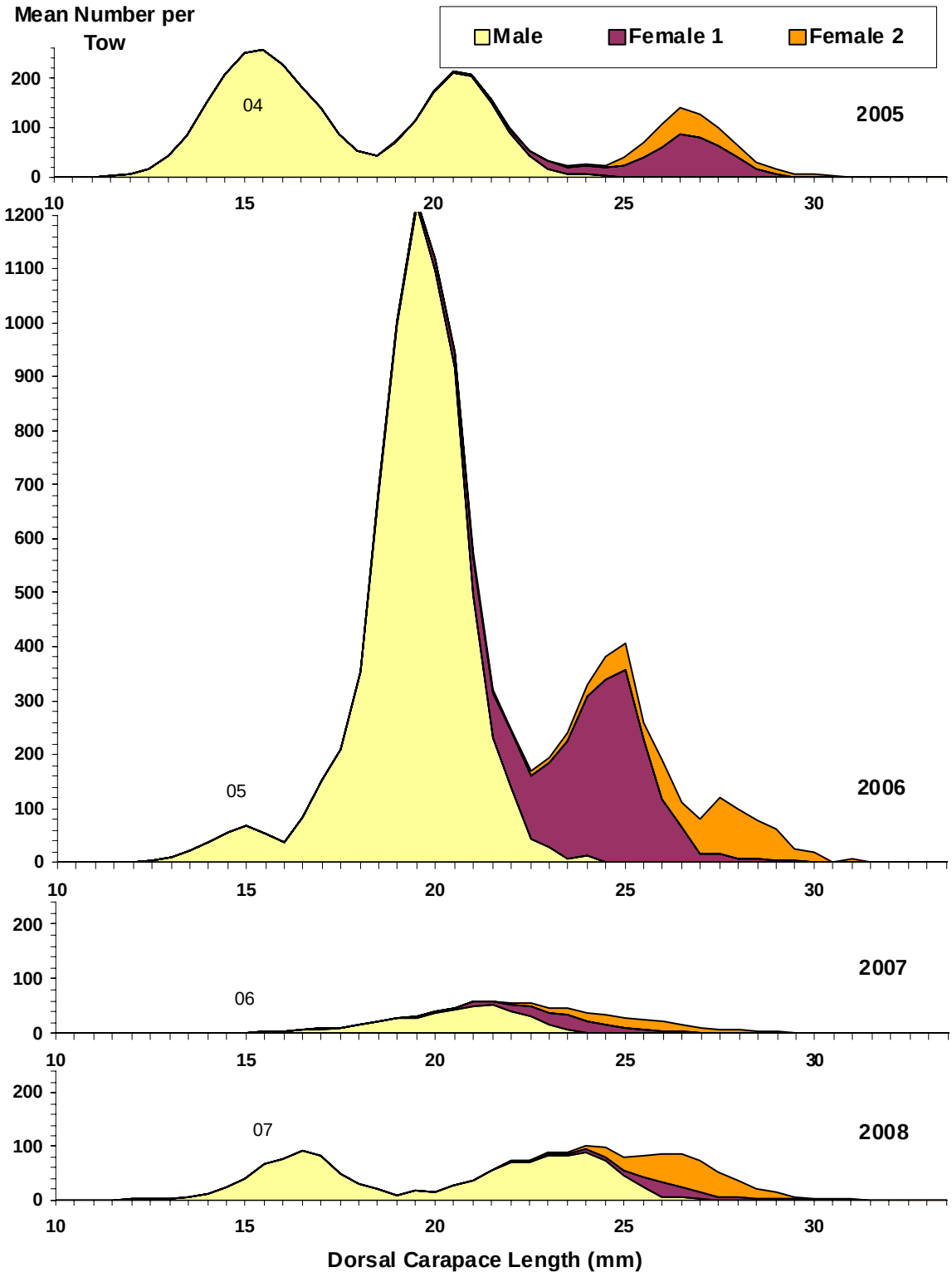


Figure 12 continued.

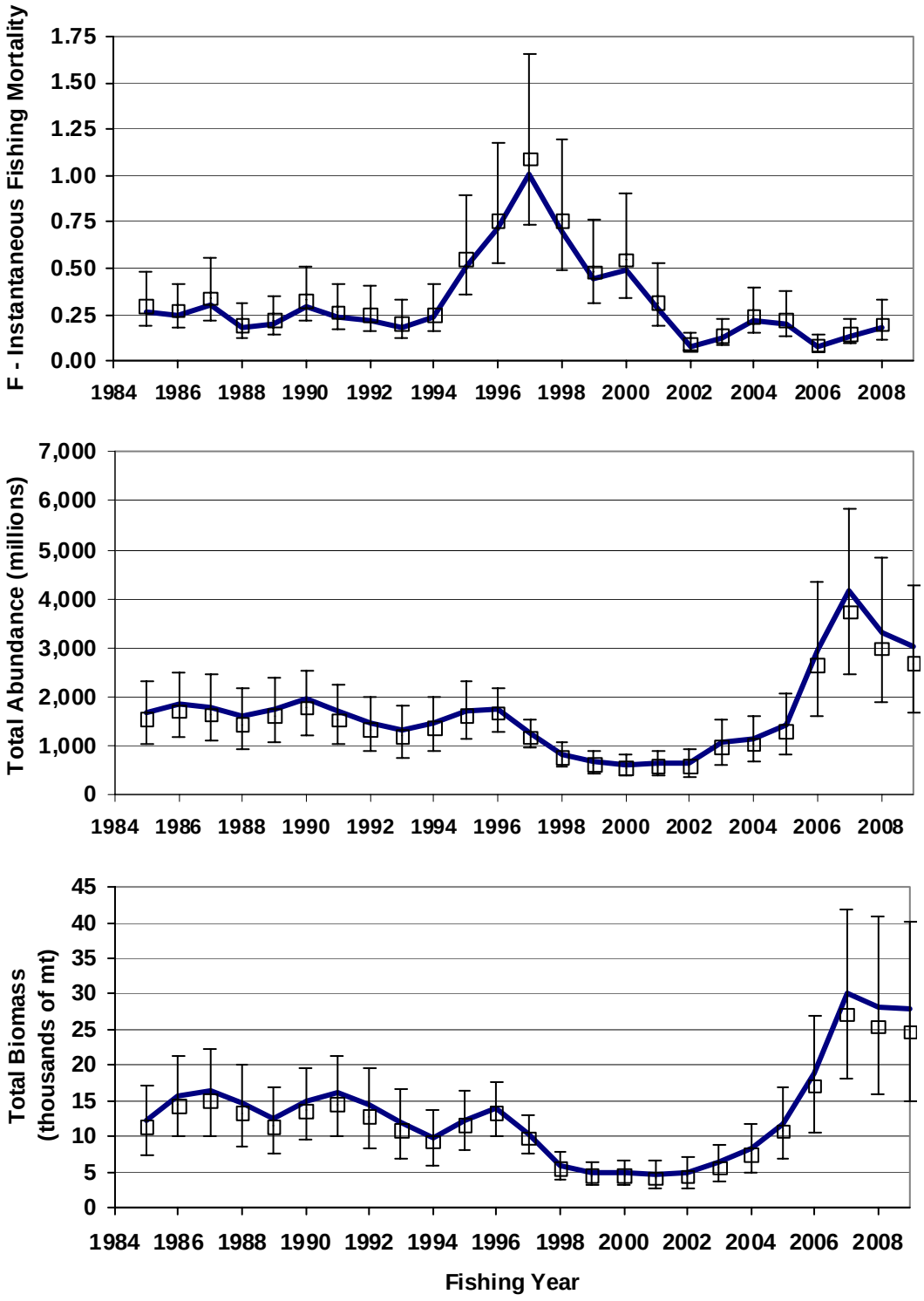


Figure 13. Fishing mortality, abundance, and biomass of Gulf of Maine northern shrimp as estimated by CSA, with least squares estimates, bootstrapped medians (square symbols), and 80% confidence intervals.

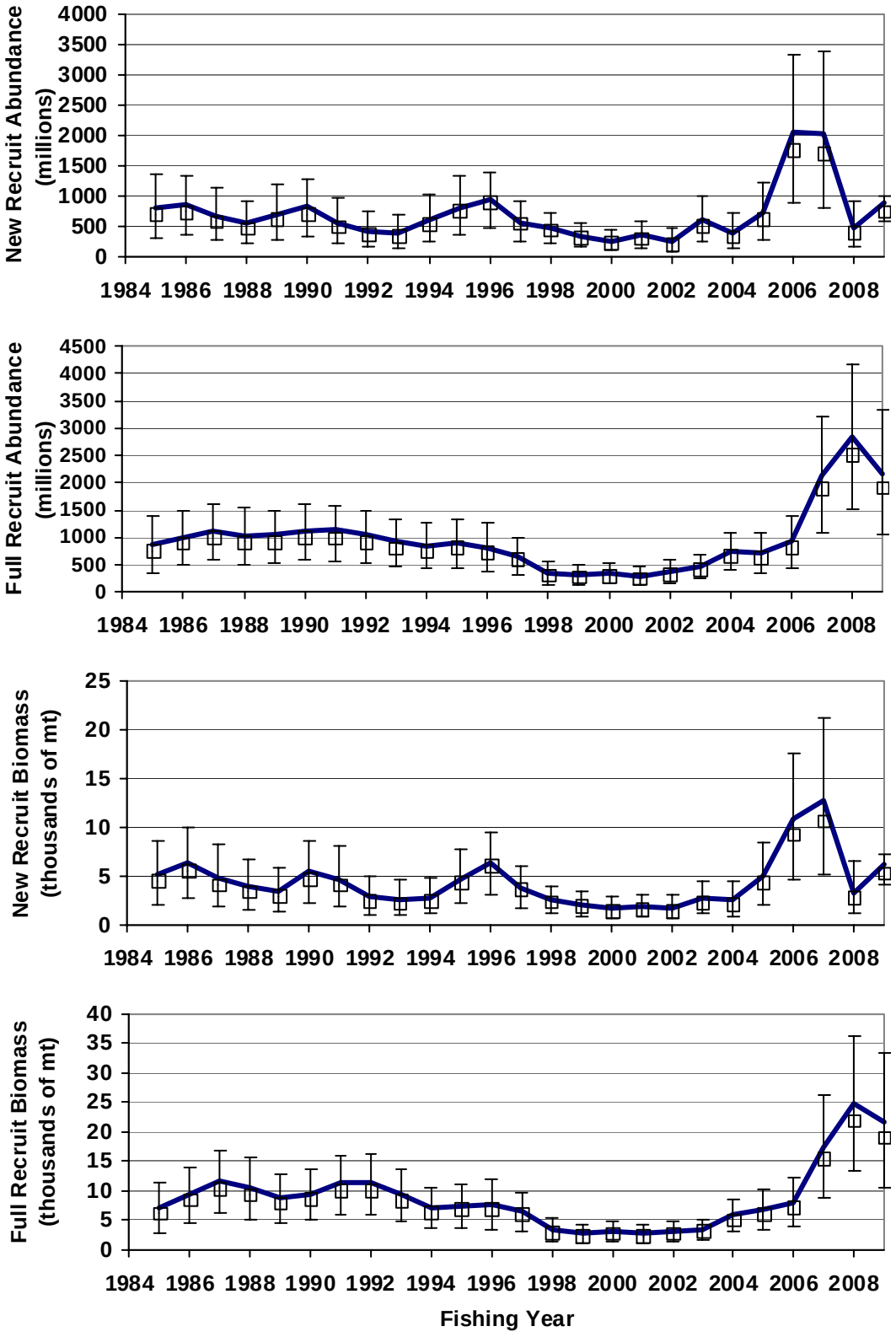


Figure 13 continued.

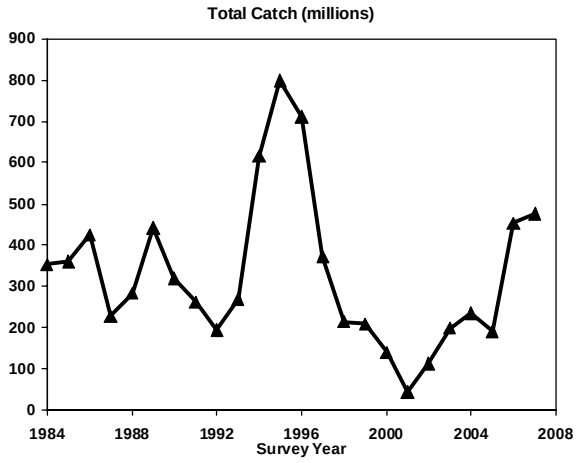
Input Data			
Survey Year*	Indices of Abundance: Recuits	Indices of Abundance: Full Recruits	Total Catch Millions*
1984	447.6	479.1	352.79
1985	611.5	913.6	361.17
1986	533.3	848.5	425.29
1987	482.9	766.9	228.43
1988	459.8	387.7	283.65
1989	701.1	817.9	442.43
1990	511.5	907.5	320.29
1991	374.3	612.1	262.43
1992	313.6	444.4	194.79
1993	410.2	320.8	270.41
1994	368.6	364.3	615.32
1995	485.8	653.3	799.37
1996	257.7	348.6	710.97
1997	257.3	267.1	373.68
1998	217.1	226.6	215.12
1999	137.4	174.6	209.28
2000	276.3	288.2	140.88
2001	171.8	196.4	44.40
2002	550.6	372.9	113.66
2003	222.9	229.9	198.34
2004	292.7	405.9	235.04
2005	1295.2	1231.7	192.22
2006	3878.3	4024.4	453.73
2007	323.2	421.0	476.23
2008	561.7	847.3	

* Survey Year data are applied to the following Fishing Year

Results			
Stock Size Estimates millions at time of Survey: Recruits	Stock Size Estimates millions at time of Survey: Full Recruits	Fishing Mortality All sizes	Total Mortality Z all sizes
809.1	868.8	0.27	0.52
857.1	997.9	0.25	0.50
677.7	1128.4	0.31	0.56
559.1	1034.7	0.18	0.43
714.2	1040.9	0.20	0.45
839.7	1118.2	0.29	0.54
567.8	1137.8	0.24	0.49
434.3	1047.8	0.22	0.47
392.5	924.3	0.18	0.43
606.7	854.7	0.23	0.48
820.4	901.3	0.51	0.76
943.6	805.0	0.71	0.96
570.0	668.4	1.01	1.26
475.3	351.4	0.70	0.95
356.1	319.6	0.44	0.69
266.3	338.6	0.49	0.74
361.0	288.8	0.28	0.53
266.0	382.7	0.08	0.33
622.4	466.3	0.13	0.38
399.9	748.0	0.22	0.47
723.1	720.2	0.20	0.45
2042.9	918.1	0.08	0.33
2027.0	2137.1	0.13	0.38
465.4	2844.7	0.18	0.43
881.4	2160.3		

Input File Name	bl_2008_ass.DAT
Tuning Dataset	Survey
Time of Survey (yr)	0
Time of Catch (yr)	0
Natural Mortality Rate	0.25
Relative Catchability: Recruits to Full Recruits s_r	0.6 - 1.0
Catchability Estimate and CV	0.6426 0.1665

Note that the recruit abundance index for the last year is NOT used in the least squares estimation. It is, however, used in conjunction with the least squares estimate of q_n and the selectivity of the recruits to calculate recruit population size in 2006



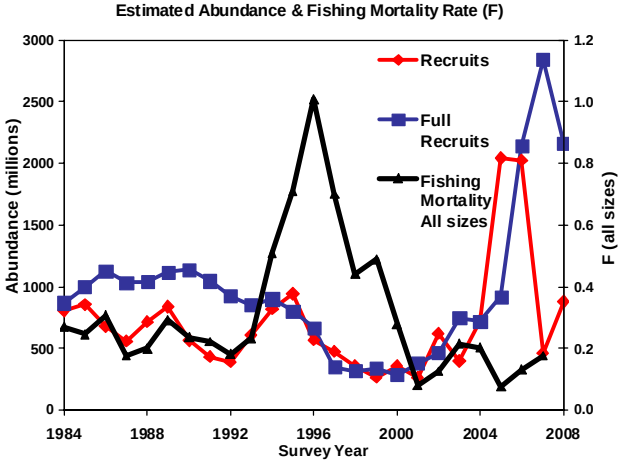


Figure 14. Catch-Survey model (CSA) input data and results.

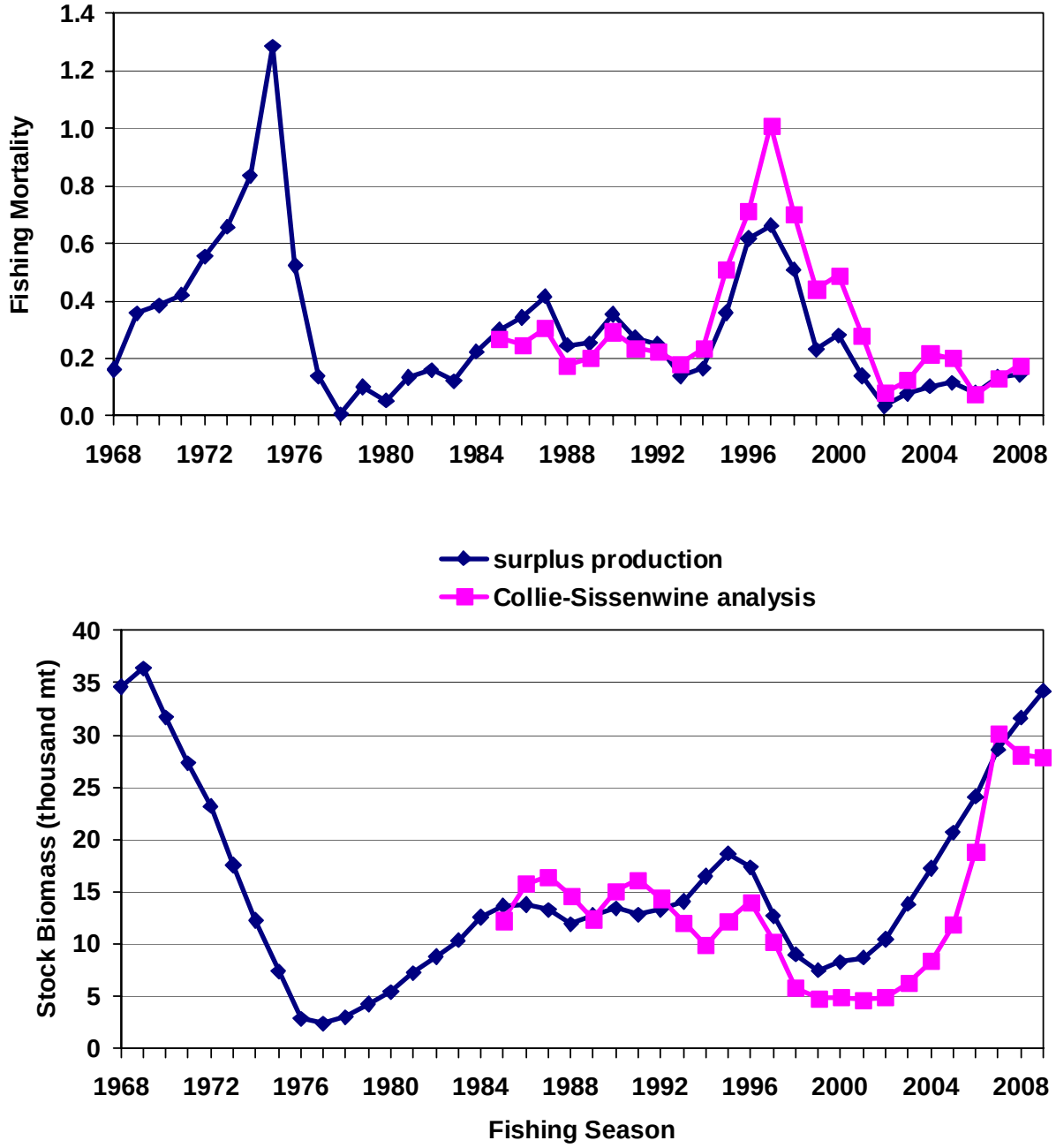


Figure 15. Estimates of fishing mortality (above) and stock biomass (below) for northern shrimp from Collie-Sissenwine analysis (CSA) and surplus production (ASPIC) modeling.

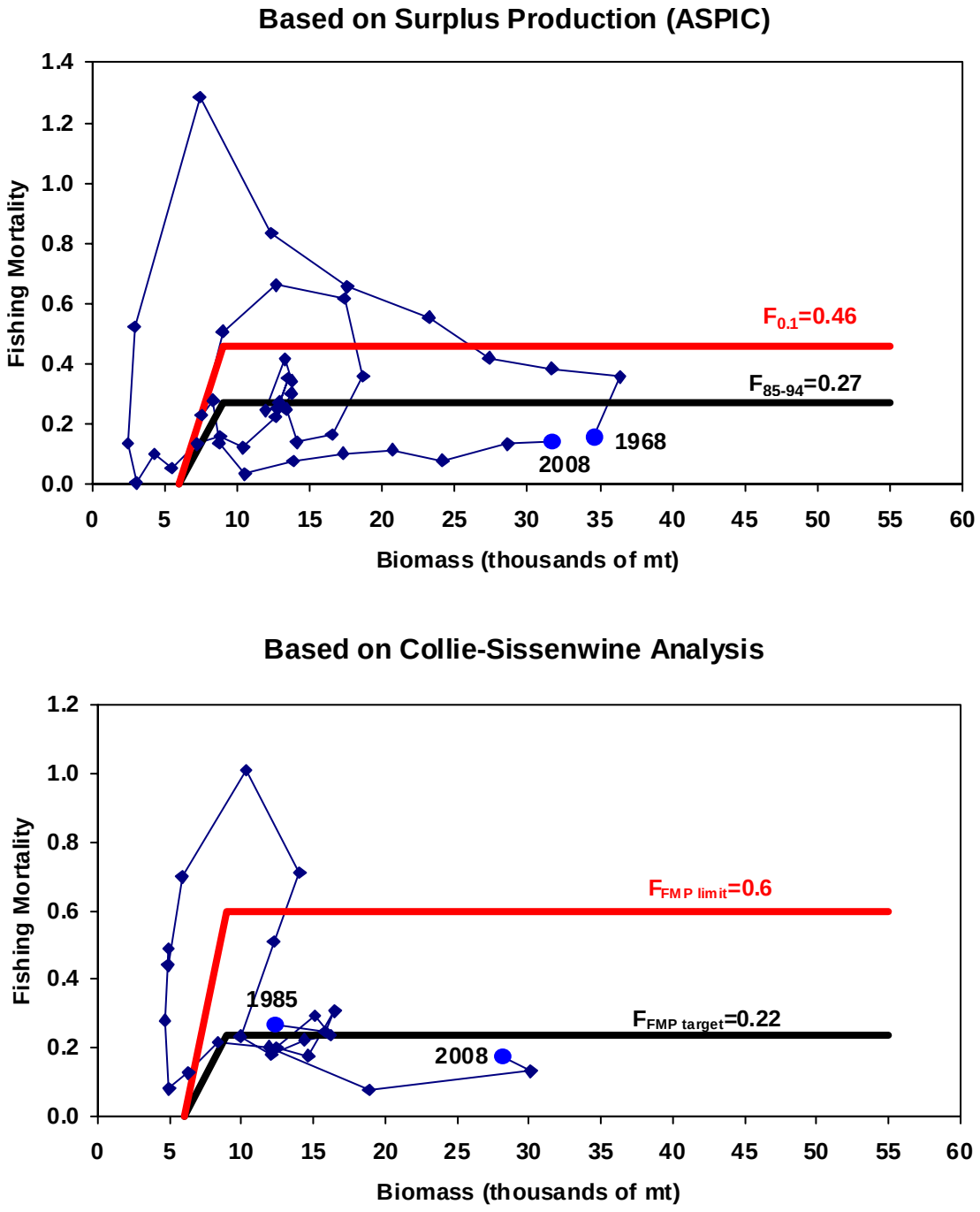


Figure 16. Biomass dynamics of the Gulf of Maine northern shrimp fishery, from surplus production (ASPIC) (above) and Collie-Sissenwine (CSA) (below) analyses, with possible fishing mortality and biomass reference points.

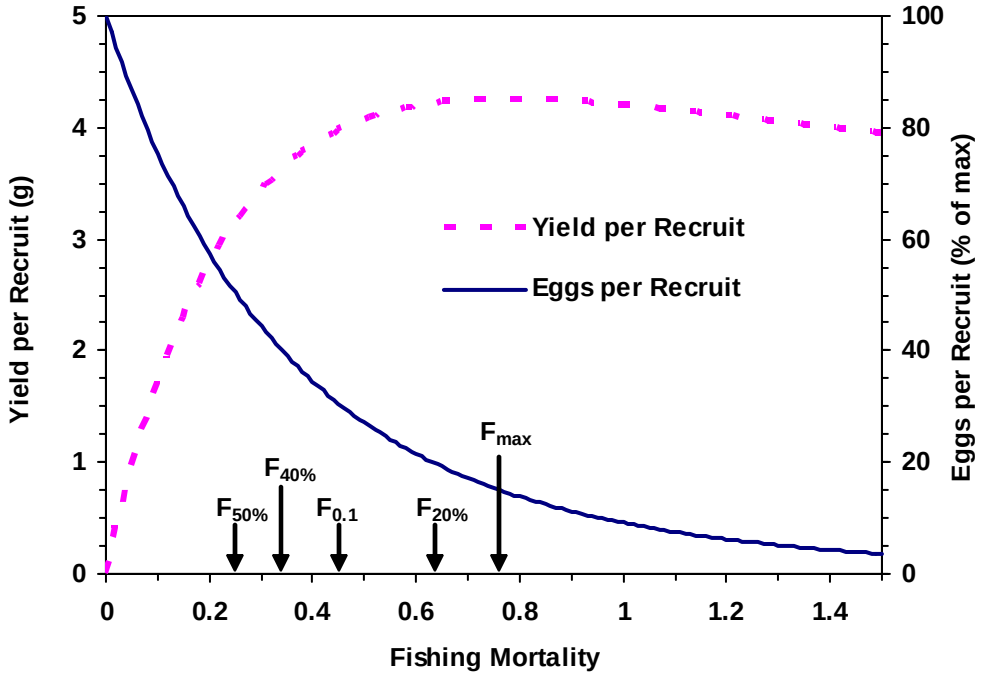


Figure 17. Yield and egg production per recruit for Gulf of Maine northern shrimp.

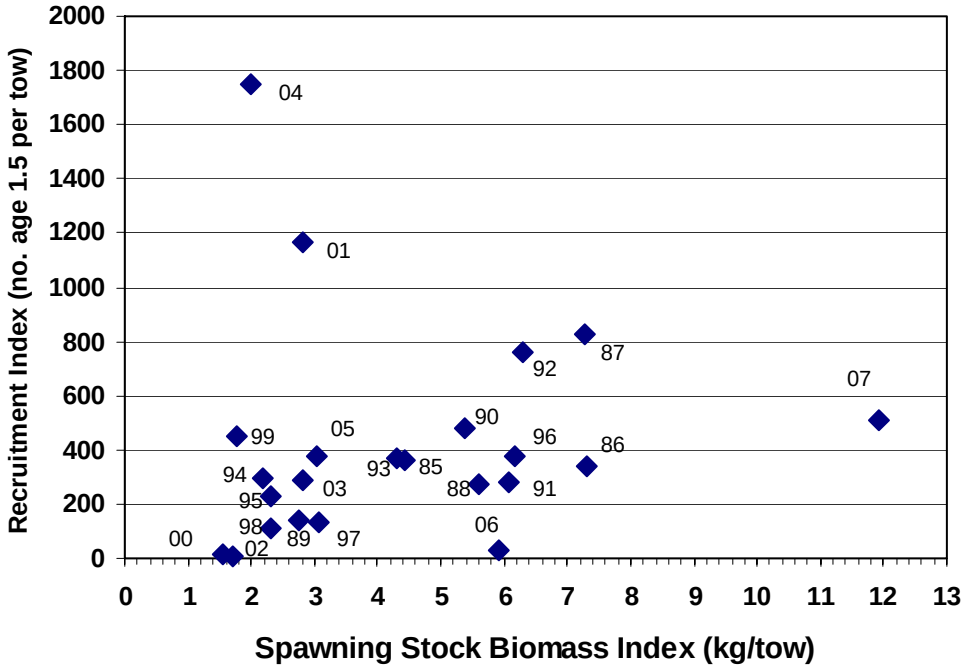
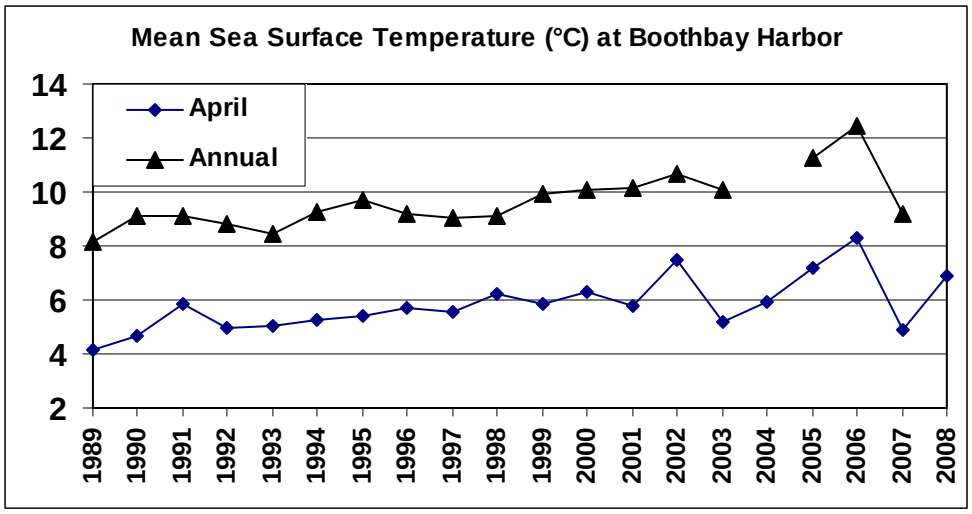


Figure 18. Relationship between summer survey index of Gulf of Maine female northern shrimp biomass the summer before spawning to age 1.5 abundance two years later. Two-digit numbers indicate the assumed age 1.5 year class.



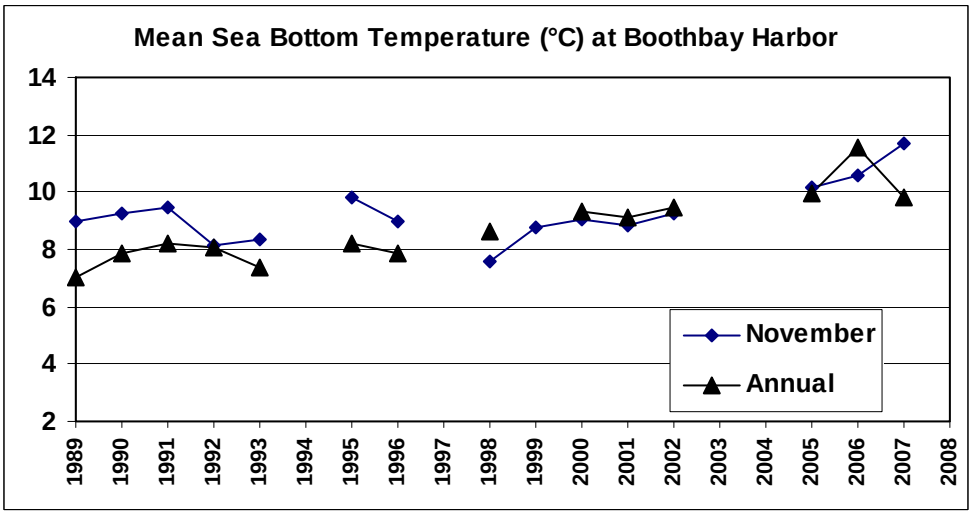


Figure 19. Sea surface (above) and sea bottom (below) temperatures in Boothbay Harbor, Maine.

Appendix A

NATURAL MORTALITY

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

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

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

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

ADDITIONAL REFERENCES

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Frechette, J. and S.S.M. Labonte. 1980. Biomass estimate, year-class abundance and mortality rates of Pandalus borealis in the northwest Gulf of St. Lawrence. In Proceedings of the International Pandalid Shrimp Symposium. Univ. Alaska Sea Grant Rep. 81-3: 307-330

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Rinaldo, R.G. 1973. Northern shrimp - assessment of some population parameters. Maine Dept. Marine Resources. Comm. Fish. Res. Dev. Proj. 3-189-R.

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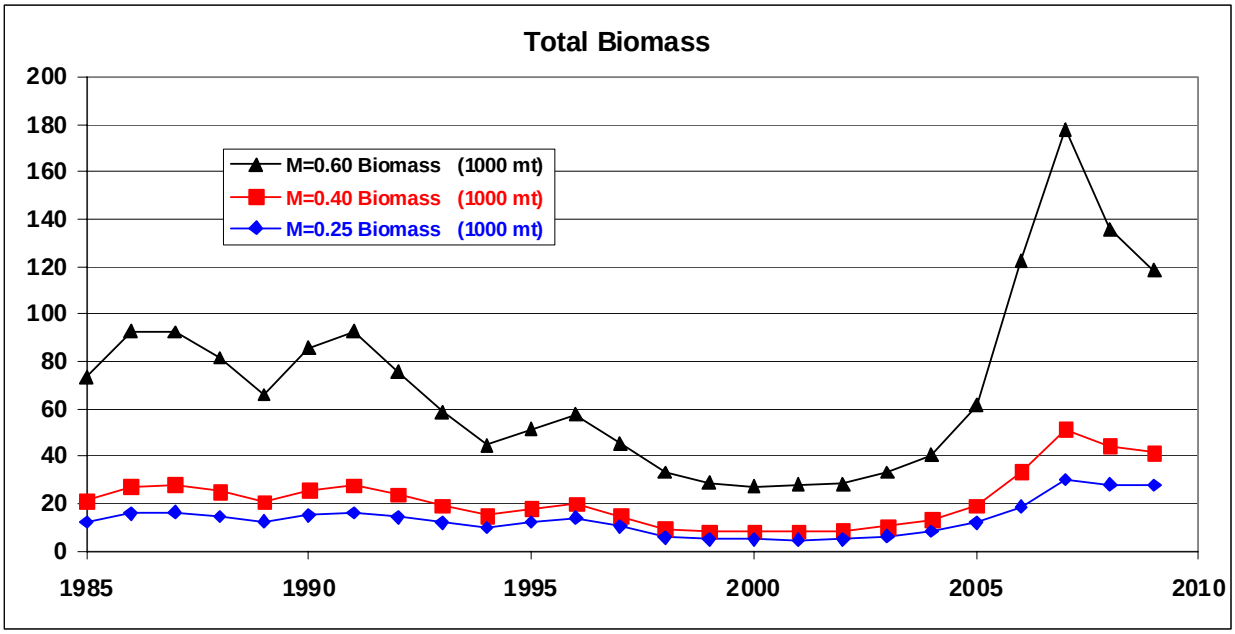
Shumway, S.E., H.C. Perkins, D.F. Schick, and A.P. Stickney. 1985. Synopsis of biological data on the pink shrimp Pandalus borealis Krøyer, 1838. NOAA Technical Report NMFS 30, 57p.



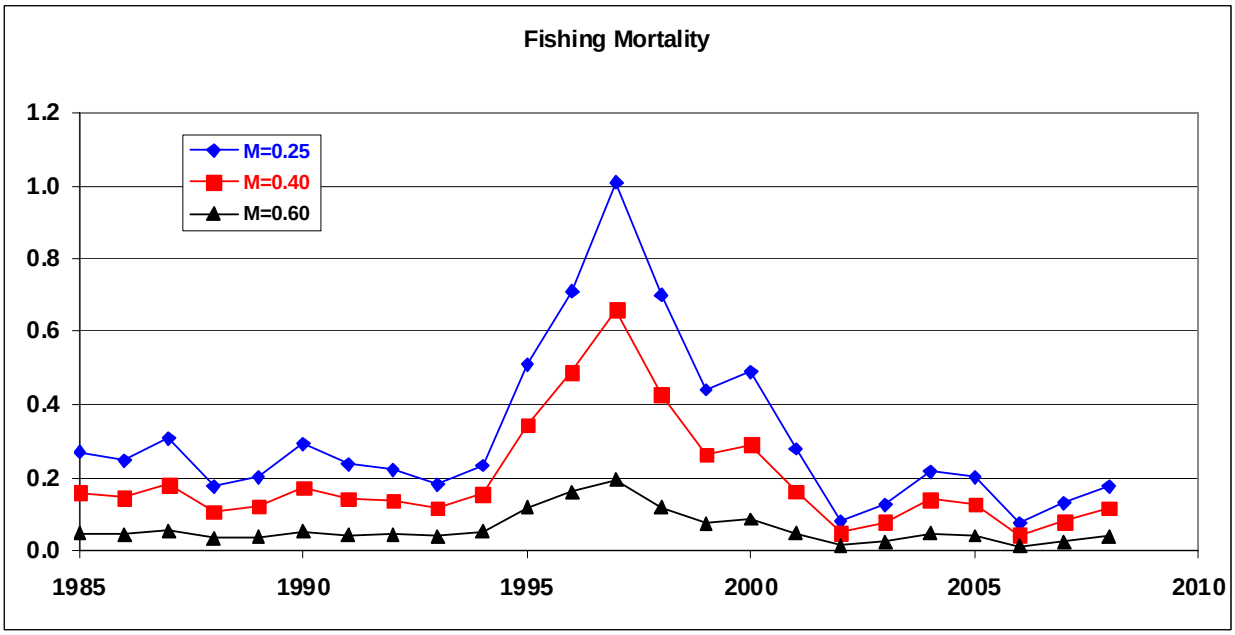


Figure A1. Biomass (above) and fishing mortality (below) of Gulf of Maine northern shrimp as estimated by CSA, assuming a natural mortality rate (M) of 0.25, 0.40, and 0.60.