ASSESSMENT REPORT

FOR

GULF OF MAINE NORTHERN SHRIMP -- 2002

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

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INTRODUCTION

Biological Characteristics

Northern shrimp (*Pandalus borealis*) 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 between 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 for Northern Shrimp was approved under the ISFMP in October 1986 (FMR No. 9., ASMFC) and northern shrimp continues to be managed under this plan today. Amendment #1 is currently under development to consider expanding the tools available to manage the fishery, anticipated for completion in late 2002 or early 2003. 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, the input from an industry advisory panel and comment from others within the shrimp fishing industry. Management under the 1986 FMP has been conducted primarily by seasonal closures and mesh size restrictions and is intended "to optimize yield, recognizing that natural fluctuations in abundance will occur" (FMP, p ii.).

Fishery Assessment

Stock assessments conducted in the 1980's and 1990's have keyed on strong year classes, (i.e. those hatched in 1982, 1987 and 1992). Each strong year class supports the shrimp fishery for about three years commencing about three years after hatching. The fishery was supported during the late 1980s and early and mid 1990s by the strong 1982, 1987 and 1992 year classes with other years depending on less robust year classes. The 1993 year class proved to be strong also, producing the first back-to-back strong year classes since the late 1960's. Based on the abundance of the 1992 and 1993 year classes, the NSTC recommended a full season for 1995-1996, but recommended reductions in fishing effort for December, April and May for the 1996-97 fishery to afford some protection for small shrimp in the offshore areas. The NSTC recommended limiting the fishery to February and March for the 1997-98 season and a 40-day season during the months of February and March in 1998-99 to protect the berried females and young shrimp in light of a rapidly declining resource. The NSTC recommended two options for the 1999-2000 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 2000-2001 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 recommend that no fishing be conducted in the 2002 season.

At its fall 2001 meeting, the Northern Shrimp Section approved a 25 day season from February 15, 2002 to March 11, 2002, inclusive. 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 following report presents the results of the Technical Committee's 2002 stock assessment. Analyses and recommendations are based on: 1) research vessel survey data collected by the Committee during summer and by the Northeast Fisheries Science Center (NEFSC) during spring and autumn, 2) 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 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 between 1988-1994, and then rose dramatically to 9,200 mt in 1996, the highest since 1973. Landings declined between 1996 and 1999 to 1,816 mt. This was followed by a slight increase to 2,390 mt in the 2000 season. The 2001 fishing season landings dropped to 1,327 m, and dropped further in the 25-day 2002 season to 375 mt, the lowest northern shrimp landings since the fishery was closed in 1978.

Maine landed 86% (322 mt) of the 2002 season total while New Hampshire and Massachusetts landed 13% (47 mt) and 1.5% (6 mt), respectively. The proportional distribution of landings among the states was similar to 2001, but has shifted gradually since the 1980's when Massachusetts accounted for about 30% of the catch, (Table 1, Figure 1).

The relative proportion of landings by month remained similar to past years. The month of February yielded the highest proportion of the catch, while March exhibited the lowest (Table 2).

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 Vessel Trip Reports (VTRs), trappers accounted for about 8.2, 9.1, and 8.2% of the three states' landings in 2000, 2001, and 2002 respectively.

Size Composition of Landings

Size composition data (Figures 2-4), collected since the early 1980's, 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 1982 year class in 1985 and 1986. The 1987 season landings of 5,300 mt (Table 1) were supported in large part by mature females (assumed age 5) from this year class. Landings declined sharply in 1988 with the passage of this year class through the fishery. A strong 1987 year class began to recruit to the fishery in spring of 1989 and was a major contributor to the 1990-1992 fisheries (NSTC Assessment Reports, 1988-1993). The 1992 year class was the first year class of notable size since 1987 and began recruiting to the fishery in March and April 1995. The 1992 year class was supplemented by a moderate sized 1993 year class, which partially supported the relatively large annual landings in 1995, 1996 and 1997. The early months of the 1998 season showed high catches from the last of the 1993 year class coming ashore as second year females. Landings were low in the 1999 season due to very poor recruitment in 1994 and 1995, and moderate recruitment in 1996. The increase in landings observed in 2000 was dominated by first year berried females from the 1996 year class. The poor landings observed in 2001 were composed primarily of egg-bearing females landed early in the season, and males caught in January, March, and April, the males accounting for approximately 30% of the catch during these months and representing the 1999 year class. This catch profile is indicative of the low survival of the females from the 1996 year class and the poor recruitment of the 1997 and 1998 year classes, which entered the 2001 fishery as transitionals and first year berried females. In the 2002 fishery, the 1997 and 1998 yearclasses (4- and 5- year old females) continued to be weak, and the moderate 1999 yearclass (3-year old males, transitionals, and early-maturing females) dominated the catches. 2-year old shrimp (2000 yearclass) were generally absent, but a noticeable quantity of 1-year-old shrimp (2001 yearclass) were caught (Figures 2-4). The high incidence of the medium-sized, 3-year-old, 1999 year class in the 2002 catches resulted in relatively high counts per pound (45 to 64, see table below).

2002 commercial shrimp fishery counts per pound, from port samples

	Pandalus borealis only		All shrimp species	
	Feb.	Mar.	Feb.	Mar.
Maine	45	55	47	57
Massachusetts	54	64	54	63
New Hampshire	51	58	51	60

Effort and Distribution of Effort

Maine trapping operations accounted for 4% to 8% of the state's total number of trips from 1987 to 1994, and for 15.9, 16.9, and 18.0% in 2000, 2001, and 2002 respectively, according to 2000-2002 Vessel Trip Report (VTR) data.

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 two occasions. The total number of trawl trips in the fishery peaked at 12,285 during the 1987 season (Table 3, Figure 5). 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 an average of 9,500 trips for the 1988, 1989, and 1990 seasons, fell further to an average of 7,900 trips in the 1991 and 1992 seasons, and declined to 6,000 trips in the 1994 season. Effort nearly doubled between 1994 and 1996 and then declined again from the 1996 level of 11,791 to 3,811 trips in 1999, 3,335 in 2000, 3,527 in 2001, and 870 in 2002 (Table 3).

Approximately 310 vessels participated in the shrimp fishery in 1997, 260 in 1998, and about 238 in 1999. In 1999, the majority (181) were from Maine, while the number of vessels from New Hampshire ports remained at about 30, and the numbers from Massachusetts declined from 33 vessels in 1998 to 27 in 1999. In 2000 and 2001 there were 285 and 274 vessels participating, respectively. In 2002, there were 133 vessels from Maine, 6 from Massachusetts, and 21 from New Hampshire, for a total of 160 vessels that reported shrimp trips.

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 2002 are still being received. The vessel logbook database is currently incomplete and has not been thoroughly audited (for an evaluation of vessel trip report data see NEFSC 1996). 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 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. As an example, the 1994 fishery stayed in deep water only through the beginning of January, shifted inshore through the middle of March and then moved into deeper water for the duration of the season. The 1995 fishing patterns revealed an early inshore migration in December and an early offshore migration with most fishing occurring offshore even during March. The 1999 season's effort was all offshore in December and almost all offshore in January. Effort moved inshore in February and remained primarily inshore throughout March. Effort in April and May was all offshore. This distribution of effort reflects the fact that the main body of shrimp available to the fleet was from the three-year-old 1996 year class, and they were split between transitionals that remained offshore and early maturing females that made some shoreward migration during the winter. During the 2000 season, effort was almost entirely inshore in January and February and increasingly offshore in March. In 2001, 17% of fishing was offshore in January, decreasing to 5% in February, increasingly offshore (78%) in March and entirely offshore in April, from Maine port interview data. In the 2002 season, 100% of fishing was inshore in February, and 20% was inshore in March, from Maine, New Hampshire, and Massachusetts port interview data.

Catch per Unit Effort

Catch per unit effort (CPUE) indices have been developed from NMFS interview data (1983-1994) and logbook data (1995-2002) and are measures of resource abundance and availability (Figure 5). They are typically measured in catch per hour 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 trip increased from 844 pounds in 1983 to over 1,300 pounds in 1985 when the strong 1982 year class entered the fishery. CPUE subsequently dropped to below 750 pounds/trip in 1988 but increased to 1,050 pounds in 1990 with entry of the strong 1987 year class. This index averaged 980 pounds between 1991-1992, declined to 767 pounds in 1993, and increased in 1994 to 1,073 pounds. The 1995, 1996 and 1997 CPUEs, from logbooks, rose sharply to 1,362 pounds in 1995, rose again to 1,714 in 1996 and declined to 1,454 in 1997. The CPUEs for 1996 and 1997 were the highest since the early 1970's. The 1998 CPUE was 1,317, showing a continued high level compared to earlier years and the 1999 CPUE dropped to 1,067 pounds per trip, which is still considerably higher than in previous years with poor recruitment. The 2000 CPUE increased to 1,444 pounds per trip. In 2001, the catch per trip dropped to 756 pounds per trip, the lowest since 1993. In 2002, the catch per trip was 872 pounds.

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 and New Hampshire's port sampling programs, and agree well with the (less precise) catch per trip data from logbooks (see text table below and Figure 5). Inshore CPUE for 2002 was 223 lbs/hr, offshore was 91, and the season average was 194 lbs/hr. (See table next page.)

ME/NH CPUE in lbs./hour towed, from port sampling. Catch in lbs./trip is from NMFS weighout and logbook data.

Year	Inshore (<55F)	Offshore (>55F)	Total	Catch/trip
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	159	146	152	1,067
2000	288	337	292	1,444
2001	100	135	109	756
2002	223	91	194	872

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). The 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. Strata sampled, and catch per tow data for the 2002 summer survey cruise are plotted in Figure 6b. The NSTC has placed primary dependence on the summer survey for fishery-independent data used in stock assessments, although NEFSC spring and autumn survey data have been valuable as well.

There has generally been good agreement between the NEFSC autumn survey index (stratified mean catch per tow, kg) and fishery trends (Figure 7). The index declined precipitously as the fishery collapsed during the 1970s; 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 1982, 1987 and 1992 year classes and the above average 1993 year class. After declining to 1.1 kg per tow in 1996, the index rose sharply in 1998 and 1999 to 2.30 and

2.54 kg per tow respectively, both well above the time series mean of 1.58 kg per tow. This is likely due to recruitment of the 1996 year class to the survey gear at age 2 in 1998 and age 3 in 1999. With the passage of the 1996 year class, and subsequent poor year classes, the 2000 fall survey index declined to 1.44 kg per tow. This trend continued in 2001, with the index dropping to 0.64 kg per tow, indicating very weak 1997 and 1998 year classes.

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the state-federal summer survey from 1984-2002 are given in Table 4, and length-frequencies by cruise are provided in Figure 9. The $\log_e$ transformed mean weight per tow averaged 15.8 kg/tow between 1984 and 1990. Beginning in 1991 this index began to decline and averaged 10.2 kg/tow between 1991 and 1996. The index then declined further, averaging 6.1 kg/tow from 1997 to 2001, and reaching a time series low of 4.3 kg/tow in 2001. In 2002 the index increased markedly to 9.2 kg/tow, still below the time series average (11.1). The total mean number per tow demonstrated the same general trends over the time series.

The stratified mean catch per tow in numbers of 1.5-year old shrimp (Table 4, Figure 8, and graphically represented as the total number in the first size modes in Figure 9) 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 year classes in 1987, 1992, and 2001, and moderately strong year classes in 1990, 1993, 1996, and 1999. The strong 1992 year class observed at (assumed) age 1.5 in the 1993 summer survey (Figure 9) was smaller than the dominant 1982 and 1987 year classes, but was followed by the above-average 1993 year class. These two year classes supported the fishery in 1996-1997. The 1996 year class appeared comparable to the moderately strong 1993 year class (Table 4, Figures 8 and 9). Recruitment between 1996 and 1999 was poor, with the 1997 and 1998 year classes being among the weakest in the time series (Figure 9). The above-average1999 year class, is comparable to the 1996 year class. The age 1.5 recruitment index was at a time series low in 2001 (2000 year class), with a stratified mean of 36 individuals per tow on the transformed scale. This reflects the poorest recruitment index observed in the 19-year history of the survey. The 2002 age 1.5 recruitment index was 1,059, which is a time series high and represents an extremely strong 2001 year class. It is also 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 relative strengths of the 1998, 1999, and 2000 year classes described above as age 1.5 recruits have been confirmed by subsequent summer surveys, that is, the assumed 1998 year class has been weak in all four surveys in which it could have been detected (1999-2002), 1999 continued to appear as a moderate year class in 2001 and 2002 surveys, and the 2000 year class was again virtually absent in 2002.

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 4, Figure 8). 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 since 1990, and has remained below the time series mean of 5.2 kg/tow (transformed) since 1995. The 2001 index of 1.5 kg/tow represented a time series low, 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. Despite the increase in 2002, the index is still well below the time series mean and reflects an overall poor spawning stock biomass.

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.

CSA (called “modified DeLury” in previous assessments) results are summarized in Table 5 and Figures 10 and 11. Abundance and catchability were relatively well-estimated, and the model fit the data well. Estimates of recruitment to the fishery averaged 0.8 billion individuals, peaked at 1.3 billion before the 1990 fishing season, but declined steadily to less than 0.4 billion before the 2002 fishing season. The current estimate indicates a sharp rise up to 1 billion prior to the next scheduled fishing year (2003). Fully-recruited abundance averaged 1.0 billion individuals and peaked at 1.5 billion before the 1991 season. Fully-recruited abundance decreased to a time series low of less than 0.4 billion in 2000 and increased to 0.6 billion in the current year. Total stock biomass estimates averaged about 13,200 mt, with a peak at over 22,000 mt before the 1991 season, and a decrease to a time series low of 5,600 mt in 1999. Total stock biomass has increased over the last three years to its current value of 9,200 mt (Table 5, Figures 10, 11).

Annual estimates of fishing mortality (F) averaged 0.34 (26% exploitation) for the 1985 to 1995 fishing seasons, peaked at 0.87 (52% exploitation) in the 1997 season and decreased to 0.28 (22% exploitation) in the 2000 season (Table 5; Figures 10, 11). In 2001, F rose to 0.40 (29% exploitation). In the most recent fishing year (2002) the short season and poor stock condition (in terms of exploitable shrimp) along with an exceptional recruitment pulse resulted in F estimates of essentially 0.0. The three year (2000 - 2002) average is 0.22 (18% exploitation). The recent pattern in F reflects the pattern in nominal fishing effort (Figure 5). 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.

An alternative method of estimating stock size and F was used to corroborate results from CSA analysis. A surplus production model was fit to seasonal catch and survey biomass indices from 1968 to 2002 (summarized in Table 6). Estimates of F from the biomass dynamics model generally confirm the pattern of estimates from the CSA model (Figures 12 & 13). F in 2002 (F = 0.03) was the lowest observed since the fishery was completely closed in 1978 (F = 0.00). This is explained by the very limited 2002 fishery. The 2002 starting biomass was at its highest level since 1997, but still remains well below highs observed in the mid 1980's through early 1990's.

Yield per recruit and percent maximum spawning potential were estimated for the Gulf of Maine northern shrimp fishery (Figure 14). Yield per recruit was maximum at F=0.77 (F_{max}) (48% exploitation) (Table 7). 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) in 1997, 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 15). Therefore, $F_{20\%}$ may be an appropriate overfishing threshold, which would result in target Fs well below 0.6. A sustainable target F may be the average F from 1985 to 1995, which was 0.34 (which allows 40% egg production per recruit) (Figure 13).

SUMMARY

Landings in the Gulf of Maine northern shrimp fishery have declined since the mid 1990's, from a high for the decade of 9,166 mt in 1996 to 375 mt in 2002, the result of low abundance of shrimp and reductions in fishing effort. The number of fishing vessels and trawl trips have dropped from about 310 and 10,734 respectively in 1997 to 160 and 870 in 2002, although vessel reporting, particularly from the Maine small boat fleet, has probably improved. Fishing mortality rates, as calculated by CSA, have declined from 0.87 in 1997 to 0 in 2002. Although generally declining, in 5 of the past 7 fishing seasons F has been above the target of 0.34

recommended by the 1997 Stock Assessment Review Committee.

Current landings, vessels, and trips are calculated from vessel trip reports (VTRs). Note that 2001 landings were incomplete when calculated from VTRs in October of 2001 (Tables 1-2, 2001 assessment), and went up by 18% when recalculated in September 2002 (Tables 1-2 here). Thus it must be assumed that 2002 vessel trip reports are also incomplete at this time. However, it is safe to say that the 2002 fishery was short, mostly inshore, with limited participation, and with relatively good catches per trip and per hour, but with high occurrences of small shrimp (assumed 3-year-old, 1999 year class).

Exploitable biomass as estimated from CSA declined from 15,500 mt in 1995 to a time series low of 5,700 in 1999. Since then the biomass estimate has risen to 9,200 mt in 2002, as a result of the appearance of the moderate 1999 year class and the strong 2001 year class. This estimate is still well below the time-series average of 13,000 mt, and below the average of the relatively stable 1985-1995 period of 17,000 mt (Table 5). The estimate of spawning stock biomass (Figure 15, arrow labeled "03") is also still well below the time-series mean.

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 since 1997, as well as low biomass estimates, can be attributed in part to the below-average recruitment of the 1994, 1995, 1997, and 1998 year classes.

In 2003, the 1997 year class will have passed out of the fishery, and the very weak 1998 year class (assumed 5-year old females), moderate 1999 year class (assumed 4-year-old females), virtually absent 2000 year class (assumed 3-year-old males, transitionals, and early-maturing females), very strong 2001 year class (assumed 2-year-old males, transitionals, and early-maturing females), and unknown 2002 year class (juveniles) will remain.

Recommendations

The Northern Shrimp Technical Committee recommends that the Section allow no fishing season which threatens the reproductive capacity of the 1999 yearclass or which allows significant catches of the 2001 year class. The Committee bases its recommendation to the Section on its assessment of current stock status, the biology of the species, and the opportunity for improving resource conditions.

Figure 13 suggests that several years of low fishing mortality will be required to rebuild the stock to time-series norms. The NSTC is encouraged by the advent of the very strong 2001 year class, but continues to be concerned about future recruitment, considering that there has been recruitment failure in 2 of the last 4 years. Because of the failure of the 1998 and 2000 year classes, the 1999 year class, as assumed 4-year-old females of moderate abundance this coming winter, represents the only significant source of egg production for the next two years (2003 and 2004). The possible lack of mature males during the 2003 summer spawning season (because of the missing 2000 year class) is also cause for concern. In 2005 the 5-year-old female year class (2000) will again be absent. For these reasons, the protection of the 1999 year class is of vital importance.

The strong 2001 year class represents a welcome opportunity to rebuild the stock, and the NSTC emphasizes the importance of protecting these small shrimp. In the 1989 fishery, when the strong 1987 year class was also two years old, that year class dominated catches (Figure 4), especially in April and May (1989 assessment). Because of an unusually high number of early-maturing females in the 2001 year class, it is possible that some of these 2-year-old shrimp will also migrate inshore, making small shrimp even more difficult to avoid. A 2003 fishery can anticipate large catches but the sizes of individual shrimp is expected to be bimodal, that is, catches are likely to be comprised of both 4-year-old and 2-year-old shrimp, possibly even inshore.

Yield-per-recruit and egg-per-recruit analyses (Table 7) show that shrimp reach both their potential weight yield and maximum egg production at about ages 4-5. Therefore, protecting small shrimp is recommended for both economical and biological reasons. Although current shrimp trawl gear can be expected to retain only 23% of two-year-old shrimp encountered (Table 7), this year class is so much more numerous than any others present that catches of it will be significant if allowed. Catches of 2-year-old males can be expected to be above 100 count per pound (Table 7). Large catches of small shrimp will result in relatively high fishing mortality rates, which will threaten reproduction in 2003, 2004, and 2005.

If a fishery in 2003 must be conducted, the committee recommends another conservative season similar to the 2002 season (25 days), constructed to maximize the successful reproduction of the female 1999 yearclass, and to protect the immature 2001 year class until it reaches both economic and reproductive usefulness. Any fishing pressure on the 1999 year class, the only significant source of egg production for the next two years, should be extremely light and should occur only after their eggs have hatched. Notice that in 2002, over 50% of the shrimp landed in Maine in February were still carrying eggs (Figure 2). The NSTC also recommends that there be no offshore fishery (early or spring) in 2003 to protect the 2001 year class, and that other measures to protect small shrimp be considered.

References

Collie, J.S. and G.H. Kruse. 1998. Estimating king crab (Paralithodes camtschaticus) abundance from commercial catch and research survey data. In Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. Edited by G.S. Jamieson and A. Cambell. Can. Spec. Publ. Fish. Aquat. Sci. 125. pp. 73-83.

Collie, J.S. and M.P. Sissenwine. 1983. Estimating population size from relative abundance data measured with error. Can. J. Fish. Aquat. Sci. 40: 1871-1879

NEFSC (Northeast Fisheries Science Center). 1996. Report of the 22nd Northeast Regional Stock Assessment Workshop (22nd SAW) Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Reference Document 96-13. pp. 118-150.

Schick, D.F., S. Cadrin, D. McCarron, A. Richards and B. Smith. 1996. MS. Assessment Report for Gulf of Maine Northern Shrimp -- 1996. Atlantic States Marine Fisheries Commission's Northern Shrimp Technical Committee. October 18, 1996. 33pp. 4 tab., 13 fig.

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Year	Maine		Massachusetts		New Hampshire		Total		$/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		(3482.0)		(247.2)		(445.2)		(4,174.4)	0.94
1999		(1523.4)		(75.7)		(217.0)		(1,816.1)	0.93
2000		(2067.3)		(109.9)		(212.3)		(2,389.5)	0.79
2001		**(1071.8)		**(49.1)		**(205.8)		**(1326.7)	0.90
2002		**(322.1)		**(5.8)		**(47.2)		**(375.0)	

*Numbers in parentheses are computed on a seasonal basis.
**Preliminary.

Table 2. Distribution of landings (metric tons) in the Gulf of Maine northern shrimp fishery by state and month, 1986-2002.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1986 Season, 203 days, Dec 1 - May 31, extended to June 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		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		573.0	436.1	35.9	26.5	0.3		1,071.8
Mass.		38.5	8.8	1.9	0.0	0		49.1
N.H.		127.4	37.2	12.1	29.0	0		205.8
Total		738.9	482.2	49.8	55.5	0.3		1,326.7
***2002** Season, 25 days, Feb 15 - Mar 11								
Maine			253.6	68.5				322.1
Mass.			3.7	2.1				5.8
N.H.			35.6	11.6				47.2
Total			292.8	82.2				375.0

* Preliminary data

3. Distribution of fishing effort (number of trawl trips) in the Gulf of Maine northern shrimp fishery by state and month, 1986-2002.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
on, 203 days, Dec 1 - May 31, extended to June 21								
	590.0	1,309.0	2,798.0	831.0	224.0	133.0	68.0	5,953.0
	128.0	235.0	225.0	320.0	194.0	133.0	159.0	1,394.0
	156.0	163.0	165.0	51.0	3.0		17.0	555.0
	874.0	1,707.0	3,188.0	1,202.0	421.0	266.0	244.0	7,902.0
on, 182 days, Dec 1 - May 31								
	993.0	2,373.0	3,073.0	2,241.0	617.0	340.0	16.0	9,653.0
	325.0	354.0	414.0	426.0	283.0	317.0	164.0	2,283.0
	67.0	164.0	175.0	95.0	28.0		32.0	561.0
	1,385.0	2,891.0	3,662.0	2,762.0	928.0	657.0		12,285.0
on, 183 days, Dec 1 - May 31								
	972.0	2,183.0	2,720.0	1,231.0	193.0	122.0		7,421.0
	28.0	326.0	426.0	315.0	26.0	57.0		1,178.0
	72.0	231.0	236.0	99.0	3.0			641.0
	1,072.0	2,740.0	3,382.0	1,645.0	222.0	179.0		9,240.0
on, 182 days, Dec 1 - May 31								
	958.0	2,479.0	2,332.0	936.0	249.0	84.0		7,038.0
	103.0	479.0	402.0	254.0	297.0	102.0		1,637.0
	120.0	369.0	312.0	69.0	16.0			886.0
	1,181.0	3,327.0	3,046.0	1,259.0	562.0	186.0		9,561.0
on, 182 days, Dec 1 - May 31								
	1,036.0	1,710.0	1,529.0	1,986.0	897.0	238.0		7,396.0
	147.0	459.0	273.0	202.0	175.0	118.0		1,374.0
	178.0	363.0	284.0	157.0	6.0			988.0
	1,361.0	2,532.0	2,086.0	2,345.0	1,078.0	356.0		9,758.0
on, 182 days, Dec 1 - May 31								
	568.0	1,286.0	2,070.0	1,050.0	438.0	139.0		5,551.0
	264.0	416.0	401.0	231.0	154.0	147.0		1,613.0
	279.0	285.0	135.0	82.0	22.0	1.0		804.0
	1,111.0	1,987.0	2,606.0	1,363.0	614.0	287.0		7,968.0
on, 153 days, Dec 15 - May 15								
	411.0	1,966.0	2,700.0	1,222.0	318.0	141.0		6,758.0
	59.0	337.0	145.0	101.0	41.0			683.0
	96.0	153.0	76.0	29.0	3.0			357.0
	566.0	2,456.0	2,921.0	1,352.0	362.0	141.0		7,798.0
on, 138 days, Dec 14 - April 30								
	249.0	1,102.0	1,777.0	1,032.0	227.0			4,387.0
	60.0	200.0	250.0	185.0	72.0			767.0
	76.0	246.0	275.0	256.0	151.0			1,004.0
	385.0	1,548.0	2,302.0	1,473.0	450.0			6,158.0
on, 122 days, Dec 15 - Apr 15								
	265.0	1,340.0	1,889.0	1,065.0	122.0			4,681.0
	58.0	152.0	147.0	83.0	15.0			455.0
	169.0	228.0	266.0	173.0	18.0			854.0
	492.0	1,720.0	2,302.0	1,321.0	155.0			5,990.0

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	879.0	2,341.0	2,641.0	1,337.0	694.0			7,892.0
Mass.	145.0	385.0	275.0	157.0	109.0			1,071.0
N.H.	189.0	331.0	279.0	359.0	344.0			1,502.0
Total	1,213.0	3,057.0	3,195.0	1,853.0	1,147.0			10,465.0
1996 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	1,341.0	2,030.0	3,190.0	1,461.0	444.0	457.0		8,923.0
Mass.	299.0	248.0	325.0	269.0	106.0	126.0		1,373.0
N.H.	331.0	311.0	389.0	248.0	155.0	61.0		1,495.0
Total	1,971.0	2,589.0	3,904.0	1,978.0	705.0	644.0		11,791.0
1997 Season, 156 days, Dec 1- May 27, two 5-day and four 4-day blocks off								
Maine	1,674.0	1,753.0	2,737.0	1,178.0	793.0	530.0		8,665.0
Mass.	184.0	226.0	245.0	114.0	7.0	1.0		777.0
N.H.	277.0	245.0	301.0	218.0	189.0	62.0		1,292.0
Total	2,135.0	2,224.0	3,283.0	1,510.0	989.0	593.0		10,734.0
1998 Season, 105 days, Dec 8-May 22, weekends off except Mar 14-15, Dec 25-31 and Mar 16-31 off.								
Maine	852.0	1,548.0	1,653.0	725.0	346.0	189.0		5,313.0
Mass.	94.0	200.0	148.0	70.0	3.0	1.0		515.0
N.H.	141.0	216.0	182.0	134.0	83.0	22.0		778.0
Total	1,086.0	1,964.0	1,983.0	929.0	432.0	212.0		6,606.0
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	190.0	556.0	1,125.0	553.0	324.0	172.0		2,920.0
Mass.	39.0	57.0	71.0	9.0	40.0			216.0
N.H.	82.0	192.0	213.0	44.0	123.0	21.0		675.0
Total	311.0	805.0	1,409.0	606.0	487.0	193.0		3,811.0
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		653.0	1,838.0	401.0				2,892.0
Mass.		23.0	100.0	27.0				150.0
N.H.		36.0	179.0	78.0				293.0
Total		712.0	2,117.0	506.0				3,335.0
***2001** Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May								
Maine		1491.0	1209.0	112.0	39.0	6.0		2,857.0
Mass.		111.0	46.0	10.0	1.0			168.0
N.H.		302.0	142.0	27.0	31.0			502.0
Total		1904.0	1397.0	149.0	71.0	6.0		3,527.0
***2002** Season, 25 days, Feb 15 - Mar 11								
Maine			502.0	195.0				697.0
Mass.			13.0	8.0				21.0
N.H.			108.0	44.0				152.0
Total			623.0	247.0				870.0

* Preliminary data

Table 4. Stratified mean numbers and weights, per tow,* of northern shrimp collected during R/V Gloria Michelle summer surveys 1984-2002.

Untransformed

Year	Total Number	Age-1.5 Number	>22 mm** Number	Weight (kg)	Weight** >22 mm (kg)
1984	3,005	48	826	22.6	8.9
1985	3,531	643	2,262	29.4	22.3
1986	3,327	703	1,688	29.7	19.6
1987	2,441	545	1,360	21.0	15.2
1988	4,310	2,812	1,012	26.6	11.7
1989	3,580	525	1,072	27.3	11.5
1990	3,021	264	2,097	29.4	22.2
1991	1,992	765	1,042	18.2	12.6
1992	1,503	443	625	12.9	7.6
1993	3,569	2,334	772	17.9	8.5
1994	3,435	1,285	849	21.1	9.3
1995	2,856	576	1,238	21.1	13.8
1996	2,651	793	1,223	20.2	13.8
1997	3,161	1,551	1,017	19.8	11.6
1998	2,319	533	676	15.1	7.4
1999	1,648	471	719	11.9	7.8
2000	1,843	997	647	11.9	7.2
2001	870	69	281	6.5	2.9
2002	3,157	2,313	571	15.0	6.3

Log_e Transformed

Year	Total Number	Age-1.5 Number	>22 mm** Number	Weight (kg)	Weight** >22 mm (kg)
1984	1,152	18	316	10.5	3.4
1985	1,849	337	1,184	17.7	11.7
1986	1,695	358	860	19.6	10.0
1987	1,385	342	854	14.8	9.5
1988	1,269	828	298	12.8	3.4
1989	1,883	276	564	17.0	6.1
1990	1,624	142	1,127	18.1	12.0
1991	1,255	482	657	11.7	8.0
1992	955	282	397	9.4	4.8
1993	1,156	757	250	9.1	2.8
1994	984	368	243	8.7	2.7
1995	1,449	292	628	13.3	7.0
1996	776	232	358	8.8	4.0
1997	762	374	245	7.7	2.8
1998	583	134	170	6.3	1.9
1999	398	114	174	5.8	1.9
2000	807	437	283	6.4	3.2
2001	451	36	146	4.3	1.5
2002	1,446	1,059	261	9.2	2.9

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

Table 5. Summary of results from Collie-Sissenwine Analysis of Gulf of Maine shrimp.

Fishing Season	New Recruits (millions)	Fully-Recruited (millions)	F (NR+FR)	Biomass (mt)
1985	987	947	0.09	14,051
1986	1,179	1,370	0.28	21,719
1987	985	1,498	0.40	22,499
1988	757	1,299	0.48	18,799
1989	1,177	987	0.18	14,220
1990	1,313	1,403	0.33	20,637
1991	829	1,519	0.44	22,190
1992	608	1,177	0.46	16,962
1993	512	881	0.42	12,396
1994	711	713	0.32	9,199
1995	975	809	0.33	12,378
1996	883	1,003	0.65	15,516
1997	534	764	0.87	11,008
1998	510	425	0.62	6,728
1999	408	391	0.46	5,791
2000	303	393	0.28	5,658
2001	445	409	0.40	6,238
2002	358	448	-0.01	6,110
2003	1,001	634		9,244
1985-1995 average	912	1,146	0.34	16,823
2000-2003 average	527	471	0.22	6,812

Table 6. Summary of results from surplus production analysis of Gulf of Maine shrimp.

	Input				Results			
Fishing Season	Fall (kg/tow)	Maine (kg/tow)	Summer (kg/tow)	Catch (mt)	Biomass (mt)	F	B/Bmsy	F/Fmsy
1968	3.2	45.8		5,708	46,330	0.13	1.53	0.73
1969	2.7	31.2		12,140	44,520	0.30	1.47	1.75
1970	3.7	40.8		11,330	36,960	0.34	1.22	1.96
1971	3.0	9.4		10,590	30,750	0.38	1.02	2.22
1972	3.3	7.0		11,220	25,300	0.51	0.84	2.99
1973	1.9	7.8		9,691	18,860	0.61	0.62	3.57
1974	0.8	4.9		8,024	13,160	0.77	0.43	4.50
1975	0.9	6.7		6,142	8,075	1.10	0.27	6.43
1976	0.6	4.8		1,387	3,660	0.39	0.12	2.29
1977	0.2	1.6		372	3,416	0.10	0.11	0.57
1978	0.4	3.2		17	4,276	0.00	0.14	0.02
1979	0.5	4.4		487	5,838	0.07	0.19	0.43
1980	0.5	2.7		339	7,363	0.04	0.24	0.24
1981	1.5	3.0		1,071	9,505	0.10	0.31	0.60
1982	0.3			1,530	11,400	0.12	0.38	0.72
1983	1.0			1,397	13,230	0.10	0.44	0.57
1984	1.9		10.47	2,951	15,600	0.18	0.52	1.06
1985	1.6		17.69	4,131	16,710	0.25	0.55	1.44
1986	2.5		19.61	4,635	16,740	0.28	0.55	1.64
1987	1.7		15.40	5,253	16,220	0.34	0.54	1.97
1988	1.2		12.76	3,031	14,930	0.20	0.49	1.15
1989	1.8		16.95	3,315	15,840	0.20	0.52	1.19
1990	2.0		18.12	4,662	16,600	0.29	0.55	1.67
1991	0.9		11.68	3,571	16,030	0.22	0.53	1.28
1992	0.6		9.43	3,444	16,550	0.20	0.55	1.19
1993	1.6		9.14	2,143	17,290	0.12	0.57	0.68
1994	2.2		8.69	2,915	19,540	0.14	0.65	0.83
1995	1.8		13.29	6,466	21,270	0.32	0.70	1.85
1996	1.1		8.77	9,166	19,440	0.55	0.64	3.19
1997	1.3		7.73	7,154	14,420	0.58	0.48	3.36
1998	2.3		6.33	4,174	10,650	0.42	0.35	2.44
1999	2.5		5.78	1,816	9,334	0.19	0.31	1.08
2000	1.4		6.39	2,389	10,350	0.22	0.34	1.31
2001	0.6		4.33	1,327	10,970	0.11	0.36	0.65
2002			9.20	375	12,930	0.03	0.43	0.15
2003					16,360		0.54	
				1971-74 average	22,018	0.57		
				1985-95 average	17,065	0.23		
				2000-03 average	11,417	0.12		

7. 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 fishing season.

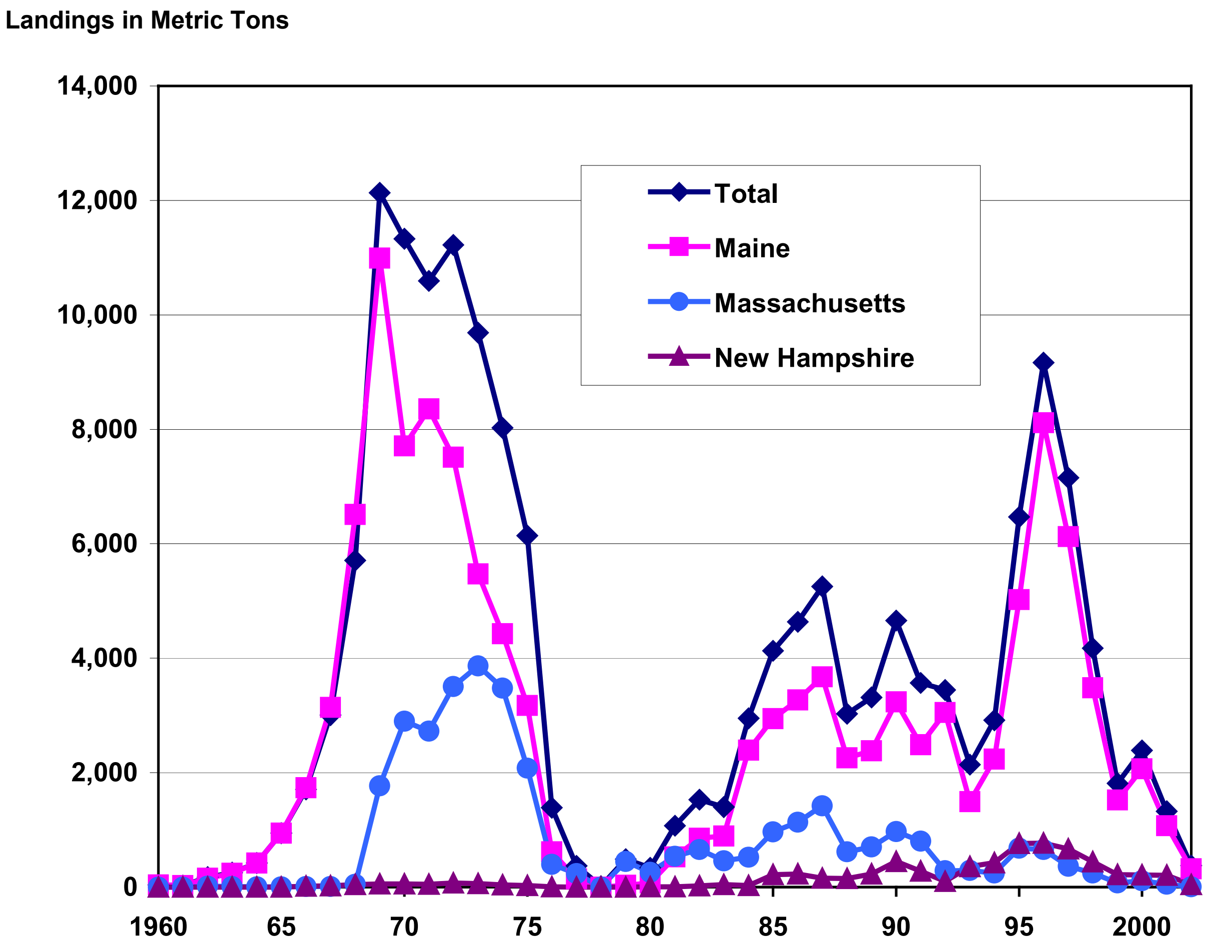


Figure 2. Length frequency distribution from samples of the Maine shrimp catch during the 2002 season.

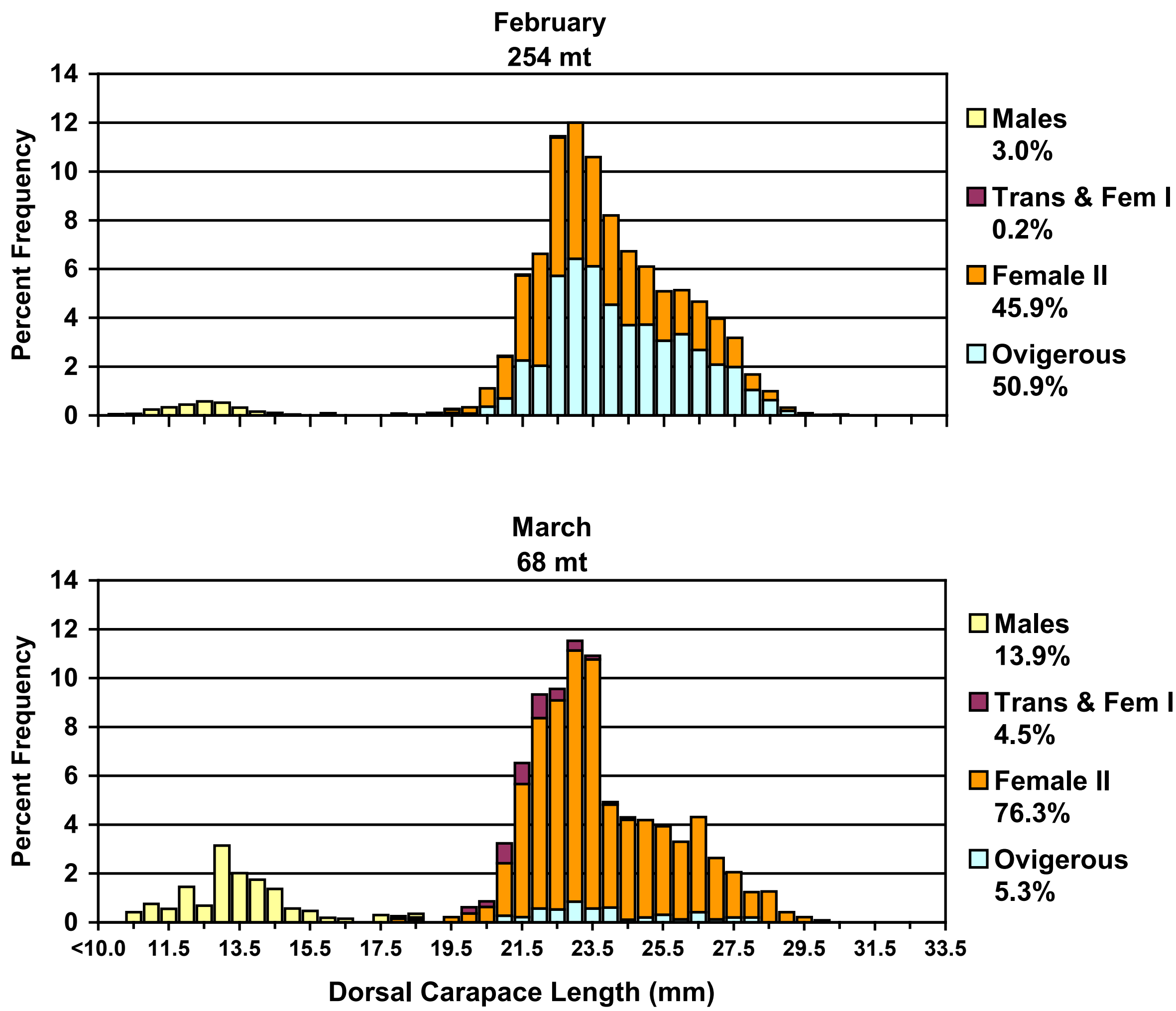


Figure 3. Length frequency distribution from samples of Massachusetts and New Hampshire shrimp catches during the 2002 season.

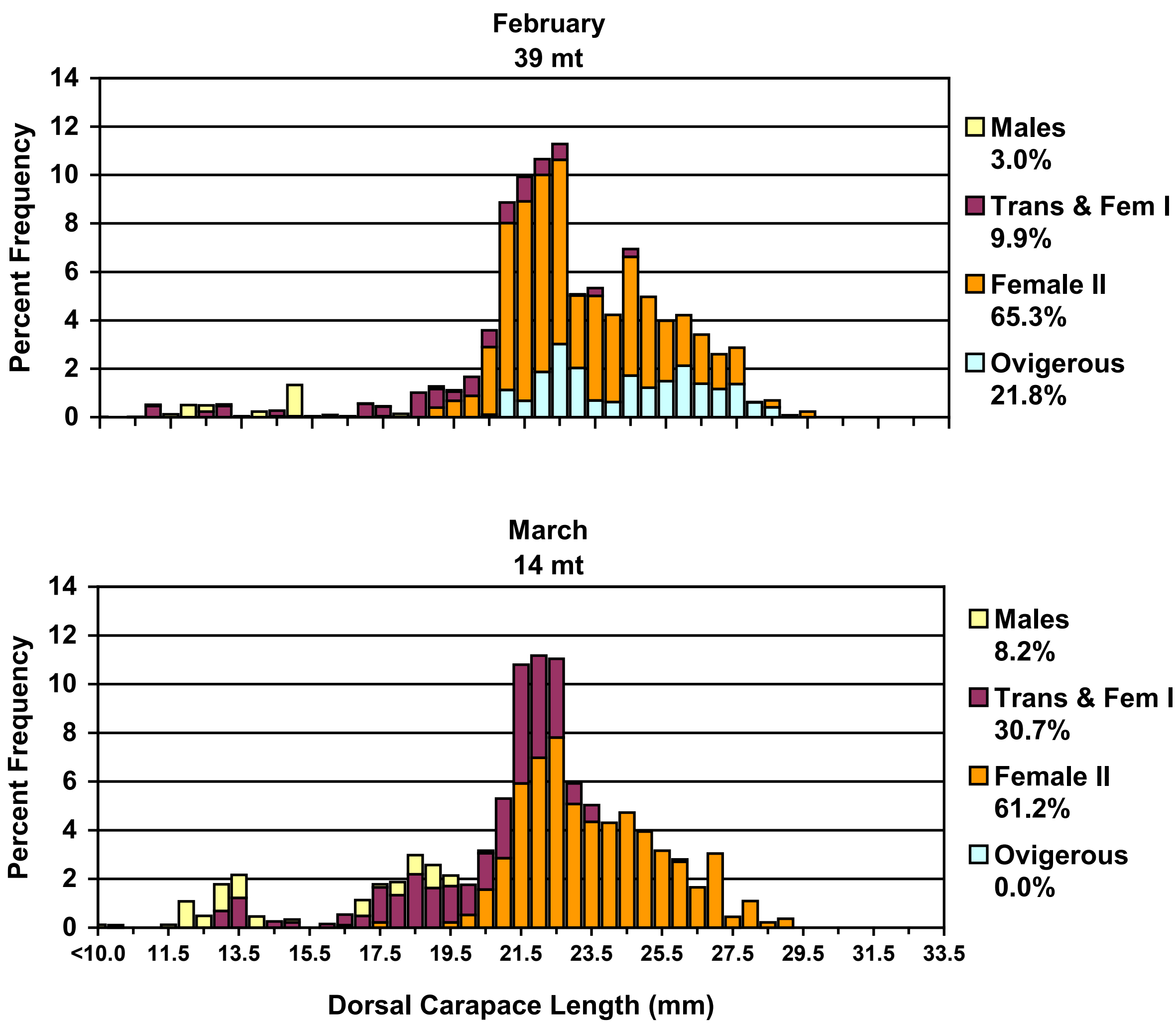


Figure 4. Gulf of Maine northern shrimp landings by length, developmental stage, and fishing season.

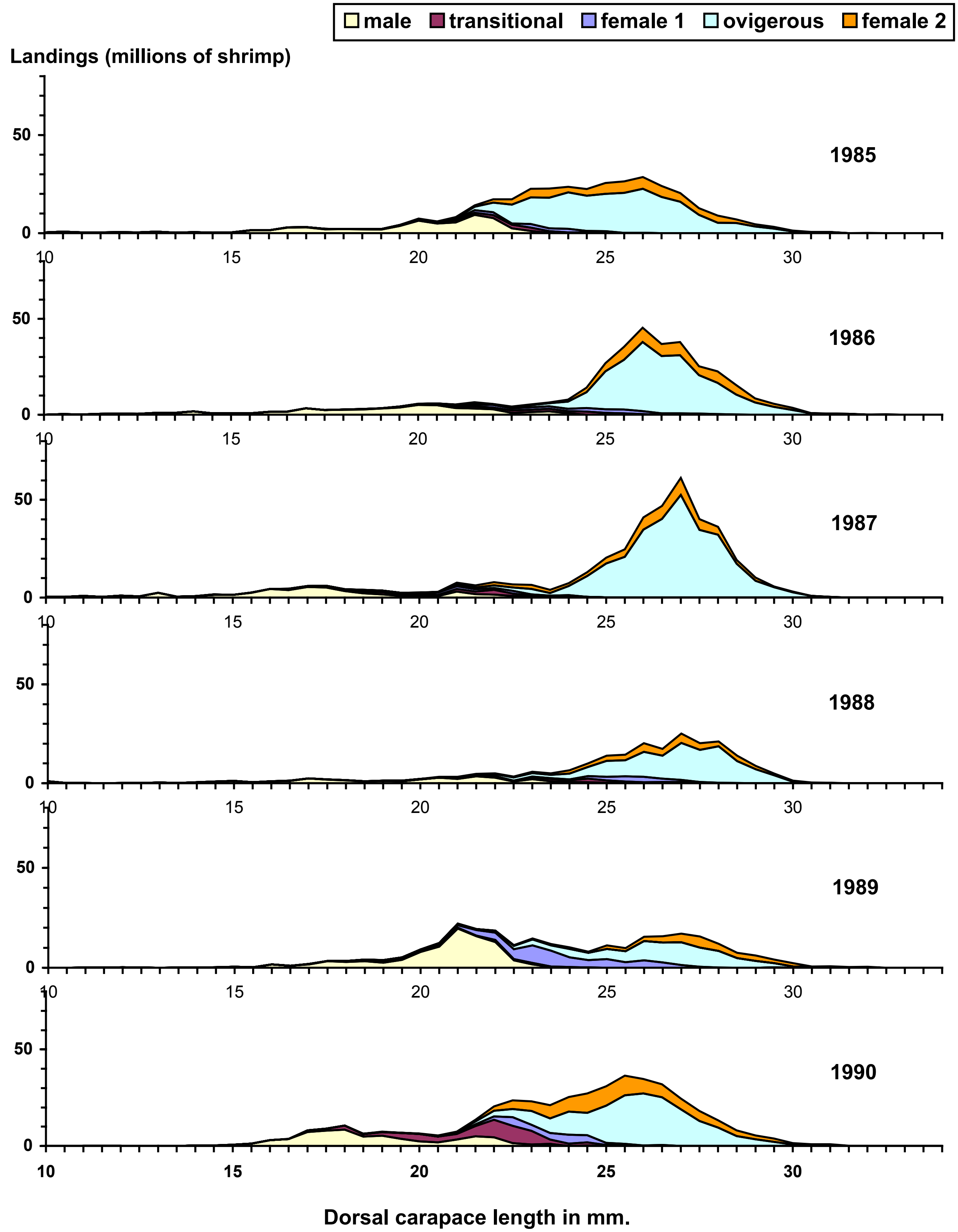


Figure 4. continued.

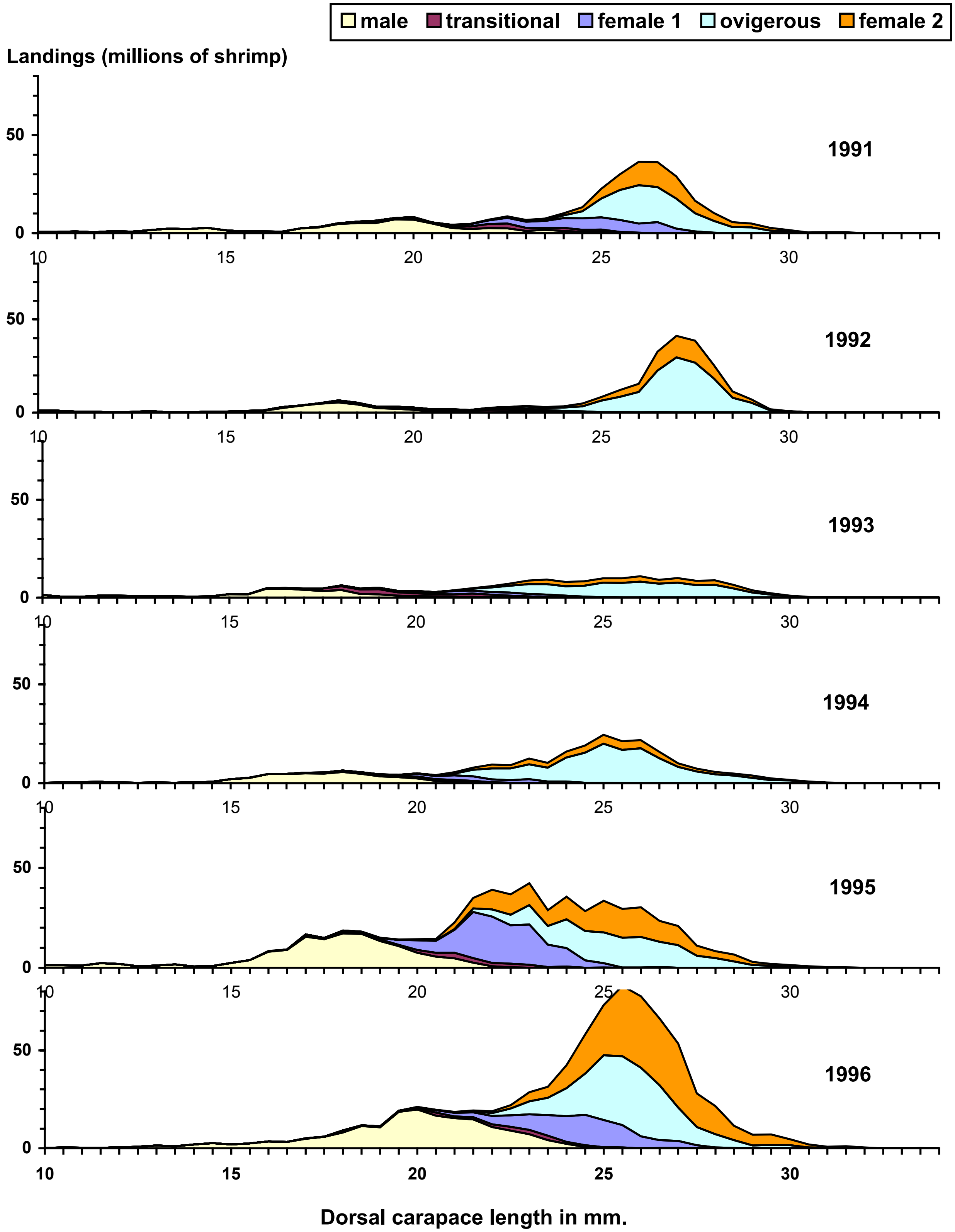


Figure 4. continued.

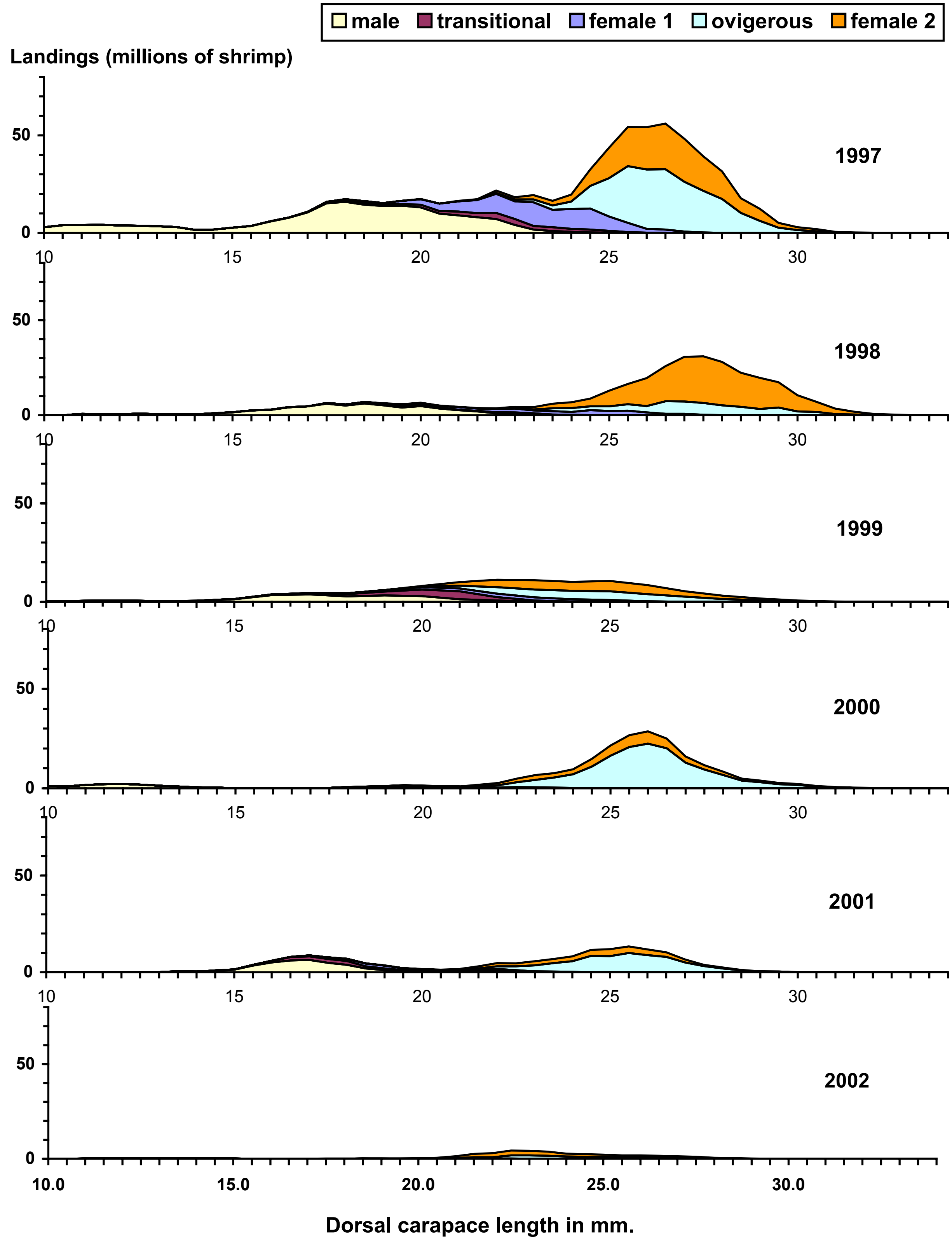
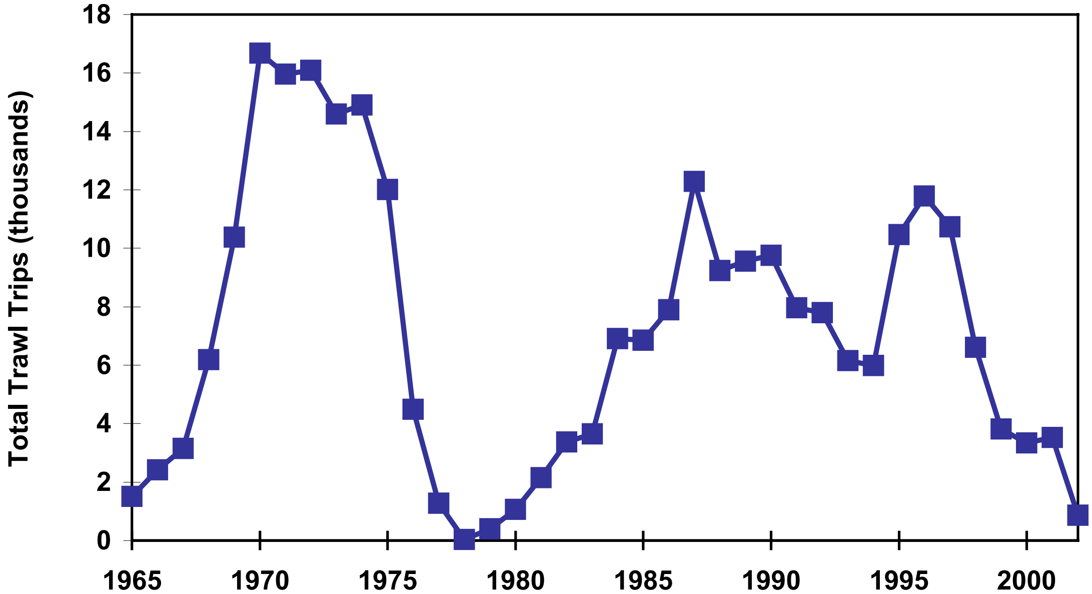
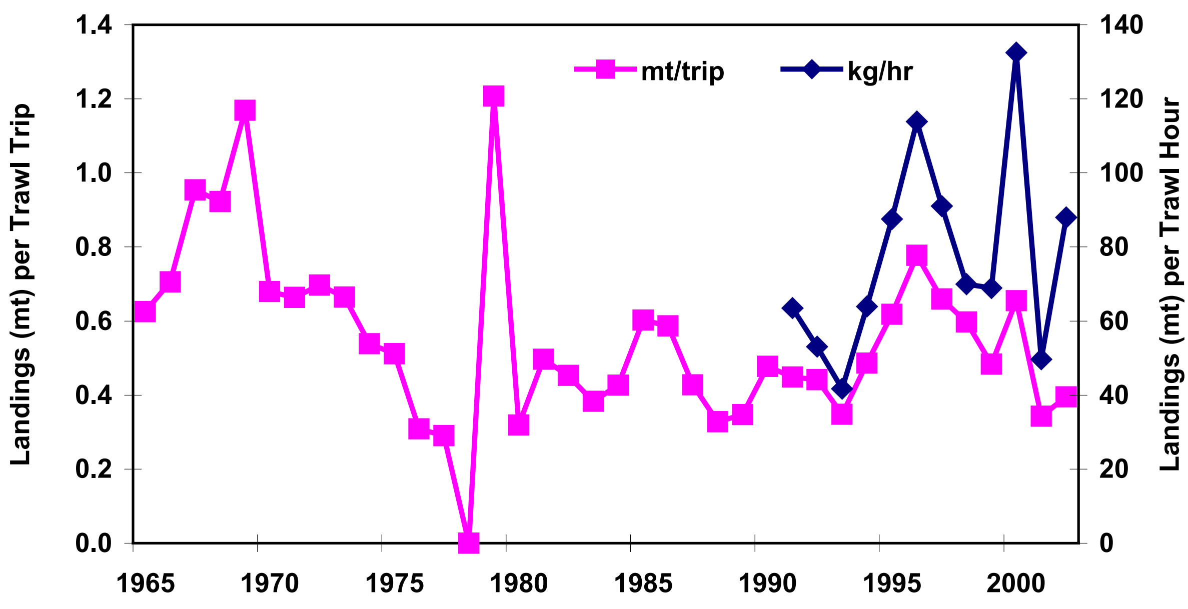


Figure 5. Nominal fishing effort (above) and catch per unit effort (below) in the Gulf of Maine northern shrimp trawl fishery.





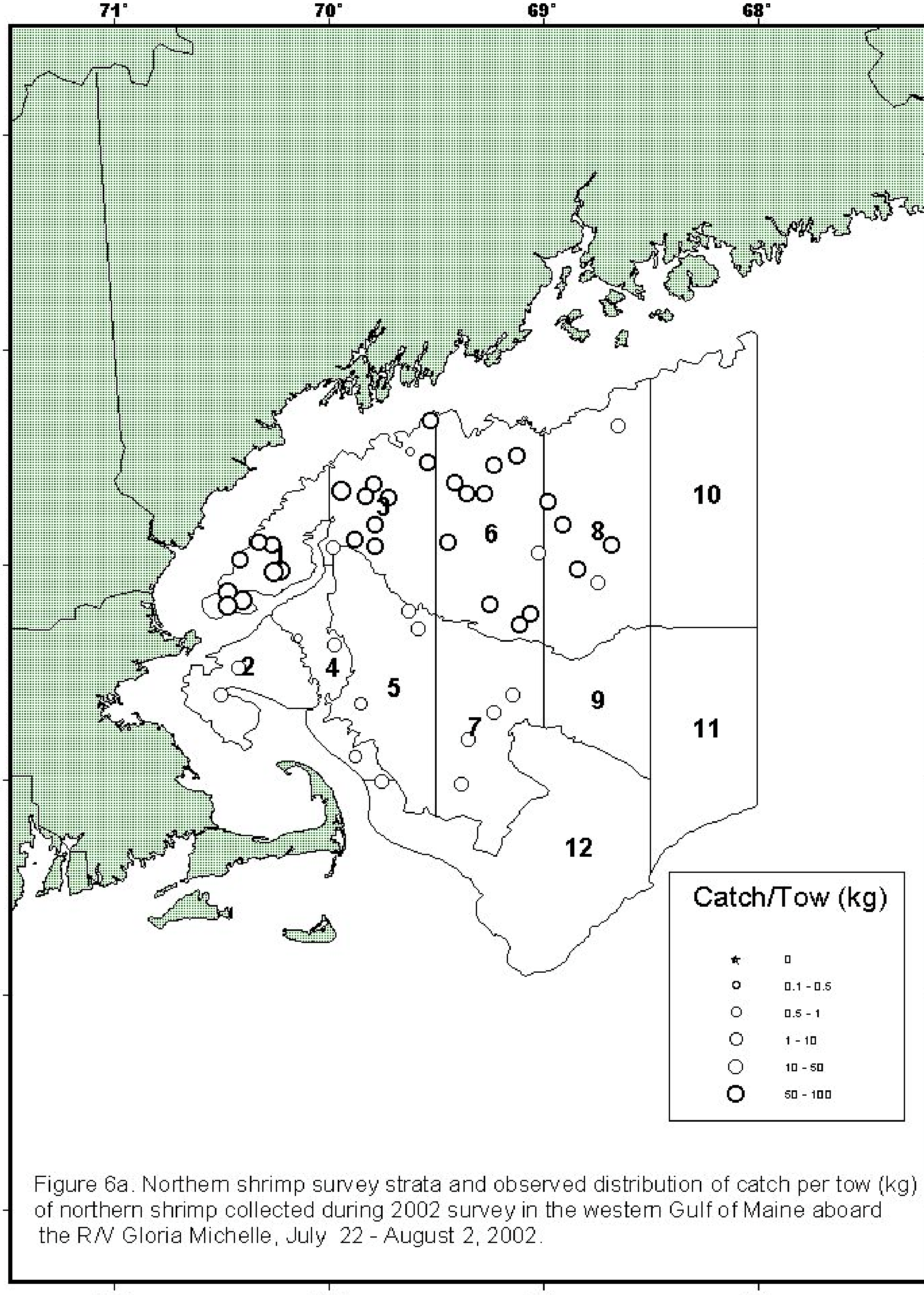


Figure 6a. Northern shrimp survey strata and observed distribution of catch per tow (kg) of northern shrimp collected during 2002 survey in the western Gulf of Maine aboard the R/V Gloria Michelle, July 22 - August 2, 2002.

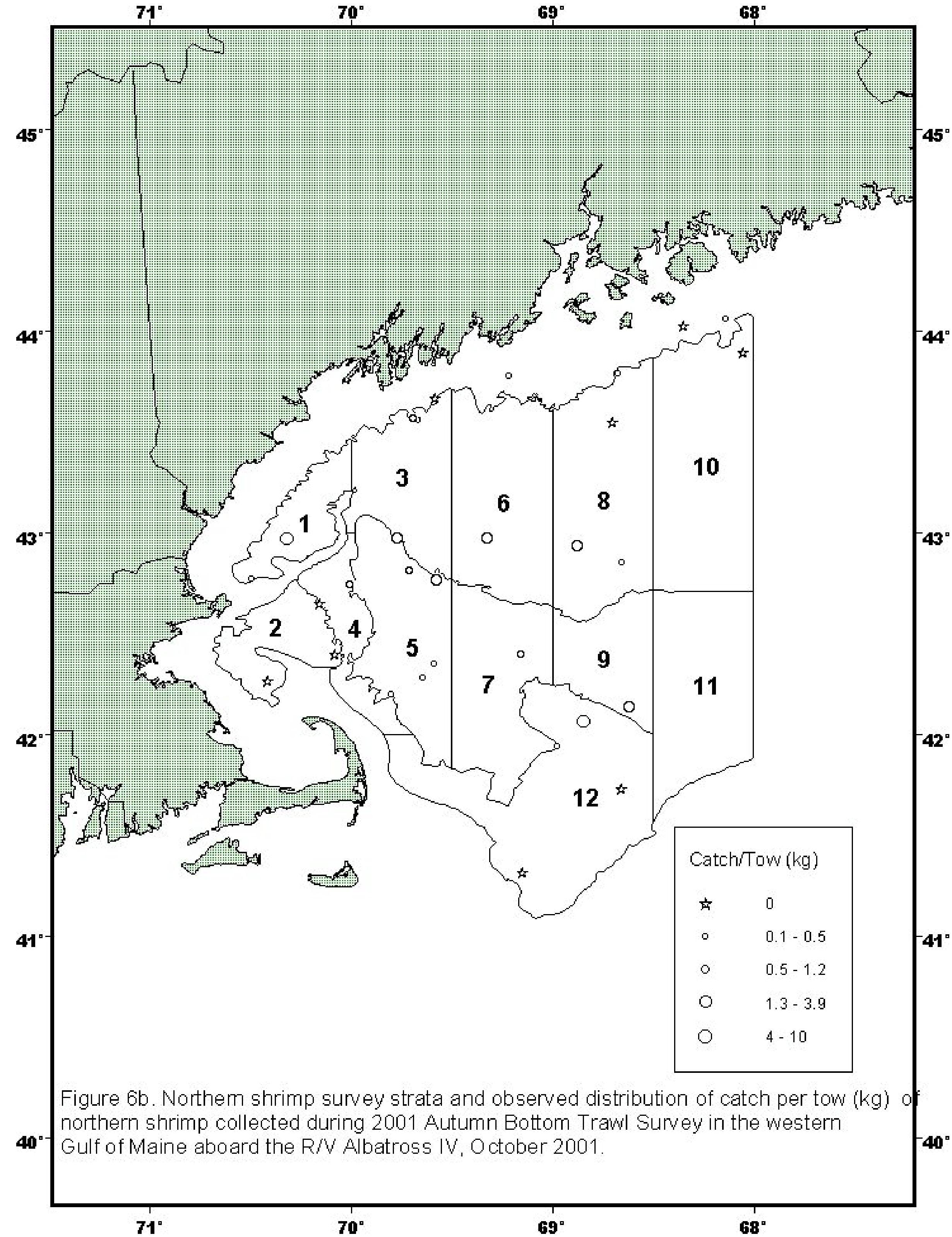


Figure 6b. Northern shrimp survey strata and observed distribution of catch per tow (kg) of northern shrimp collected during 2001 Autumn Bottom Trawl Survey in the western Gulf of Maine aboard the R/V Albatross IV, October 2001.

Figure 7. Fall survey index and landings of Gulf of Maine northern shrimp the following season.

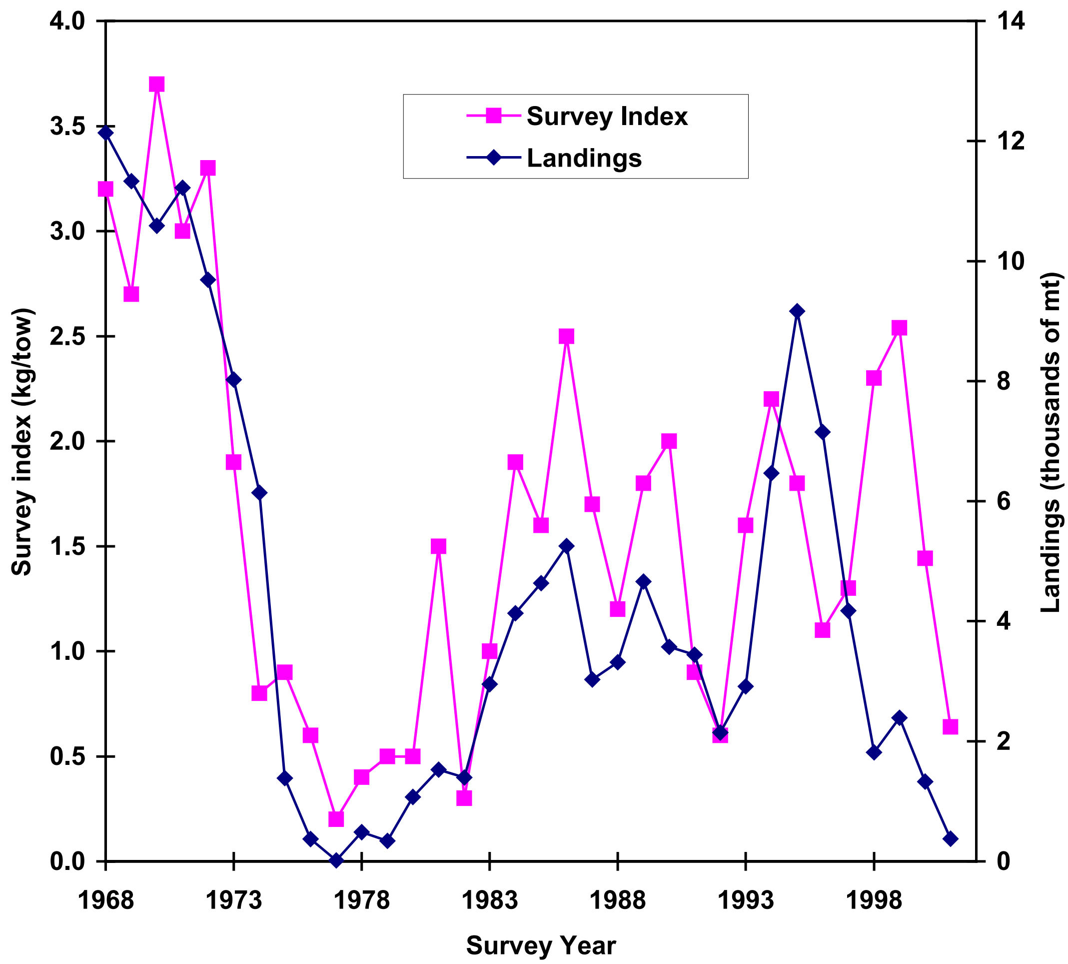


Figure 8. Gulf of Maine northern shrimp summer survey indices of abundance and biomass.

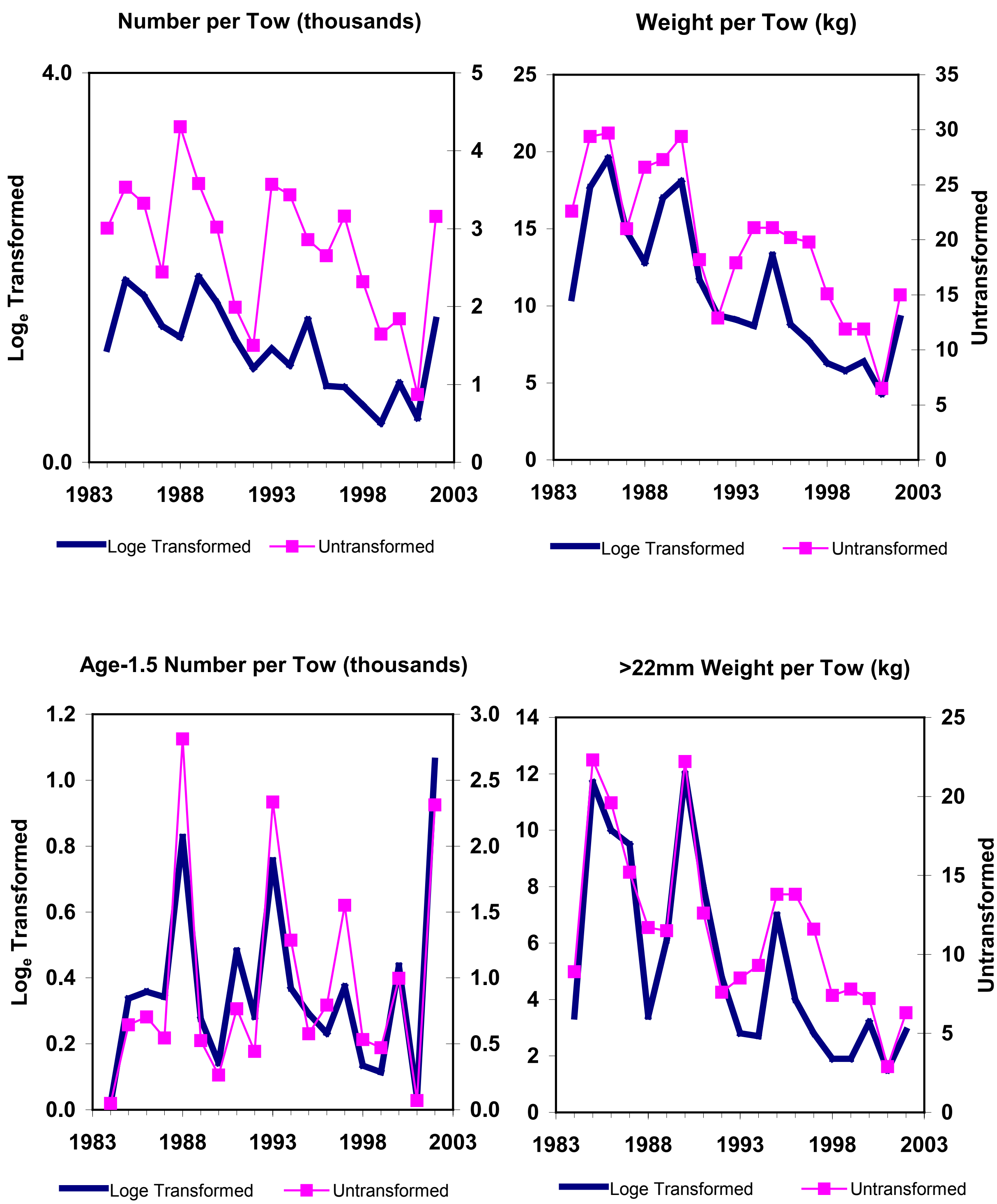


Figure 9. Gulf of Maine northern shrimp summer survey mean catch per tow by length and development stage. 2-digit numbers are assumed 1.5 age year class.

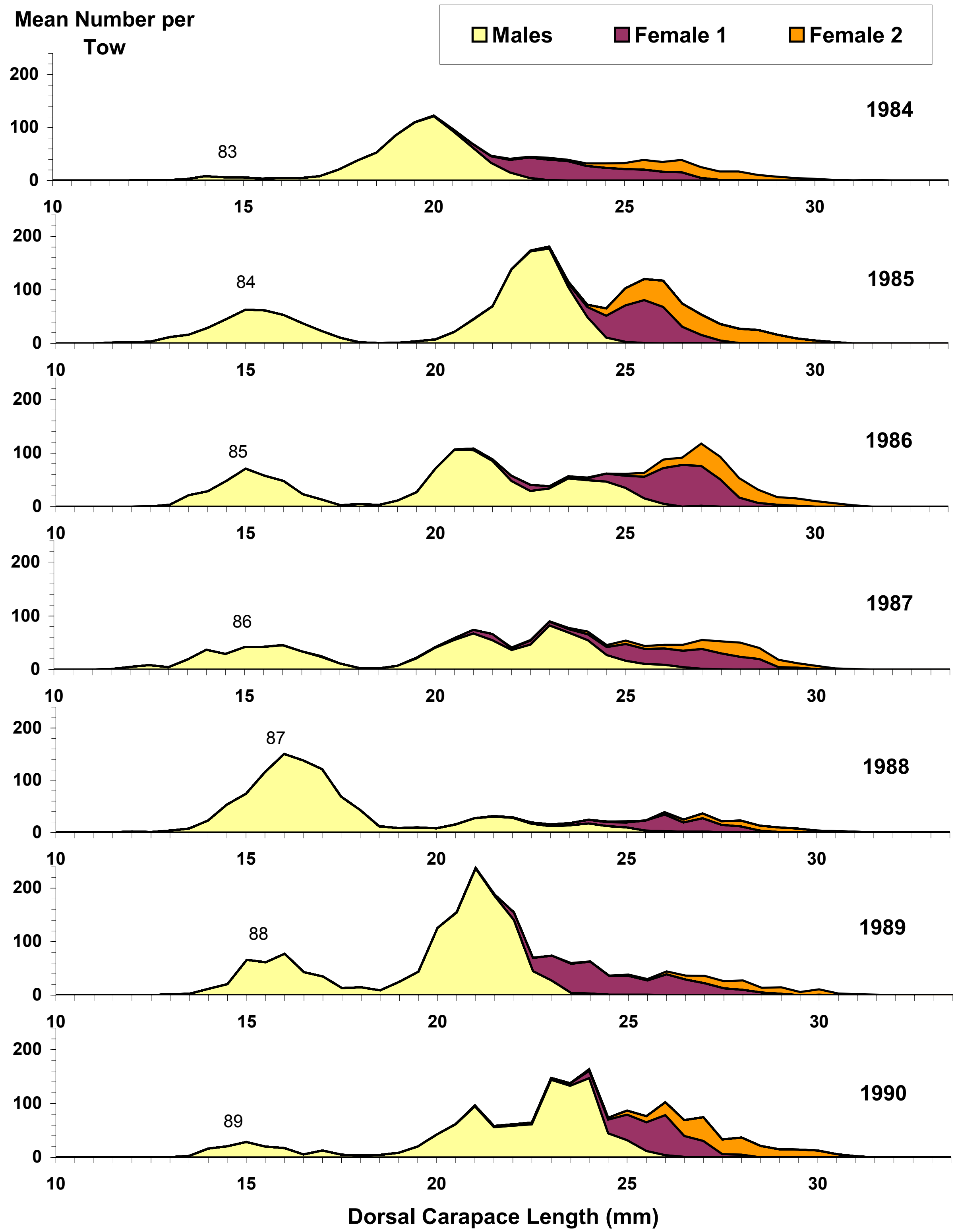


Figure 9. continued

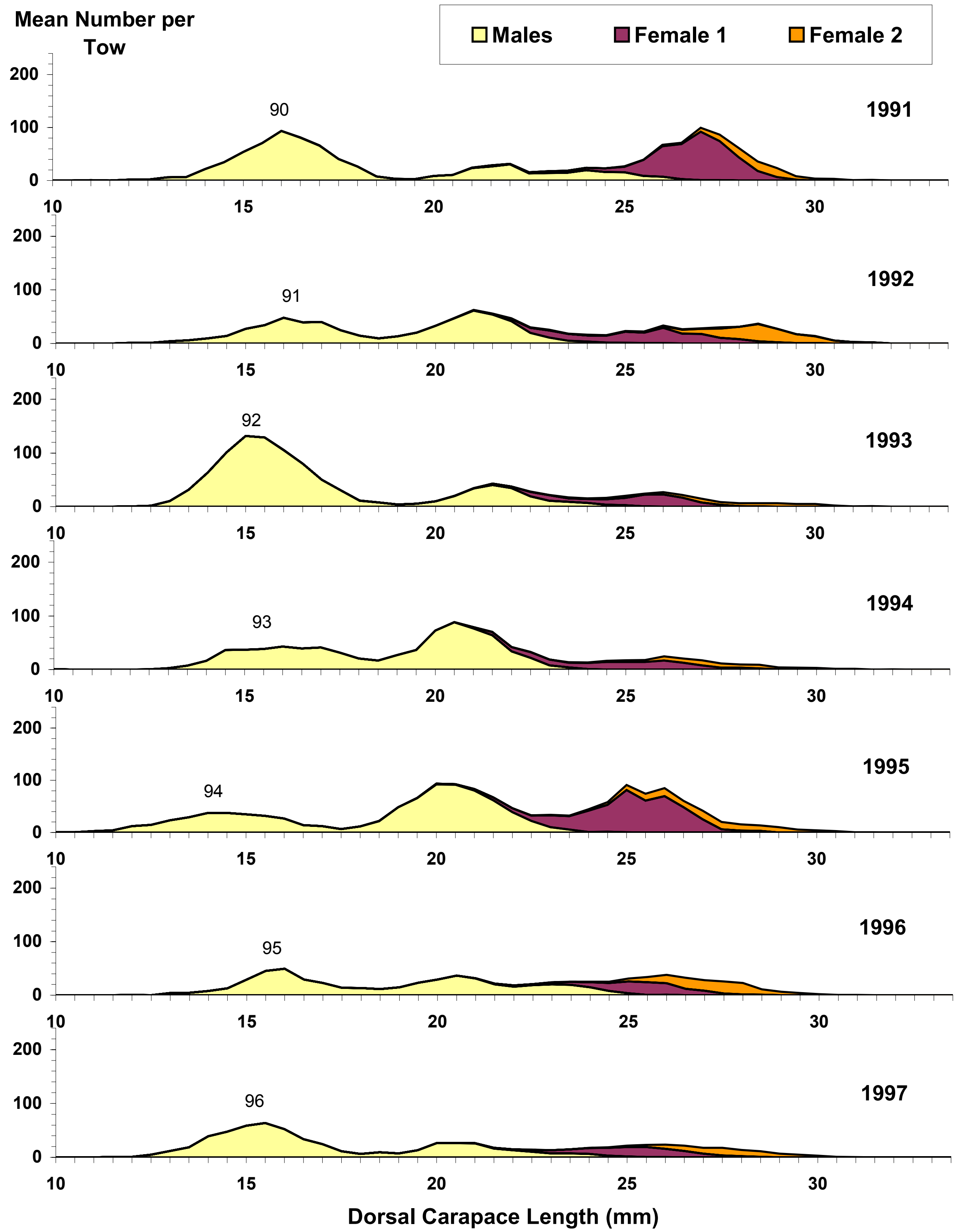


Figure 9. continued

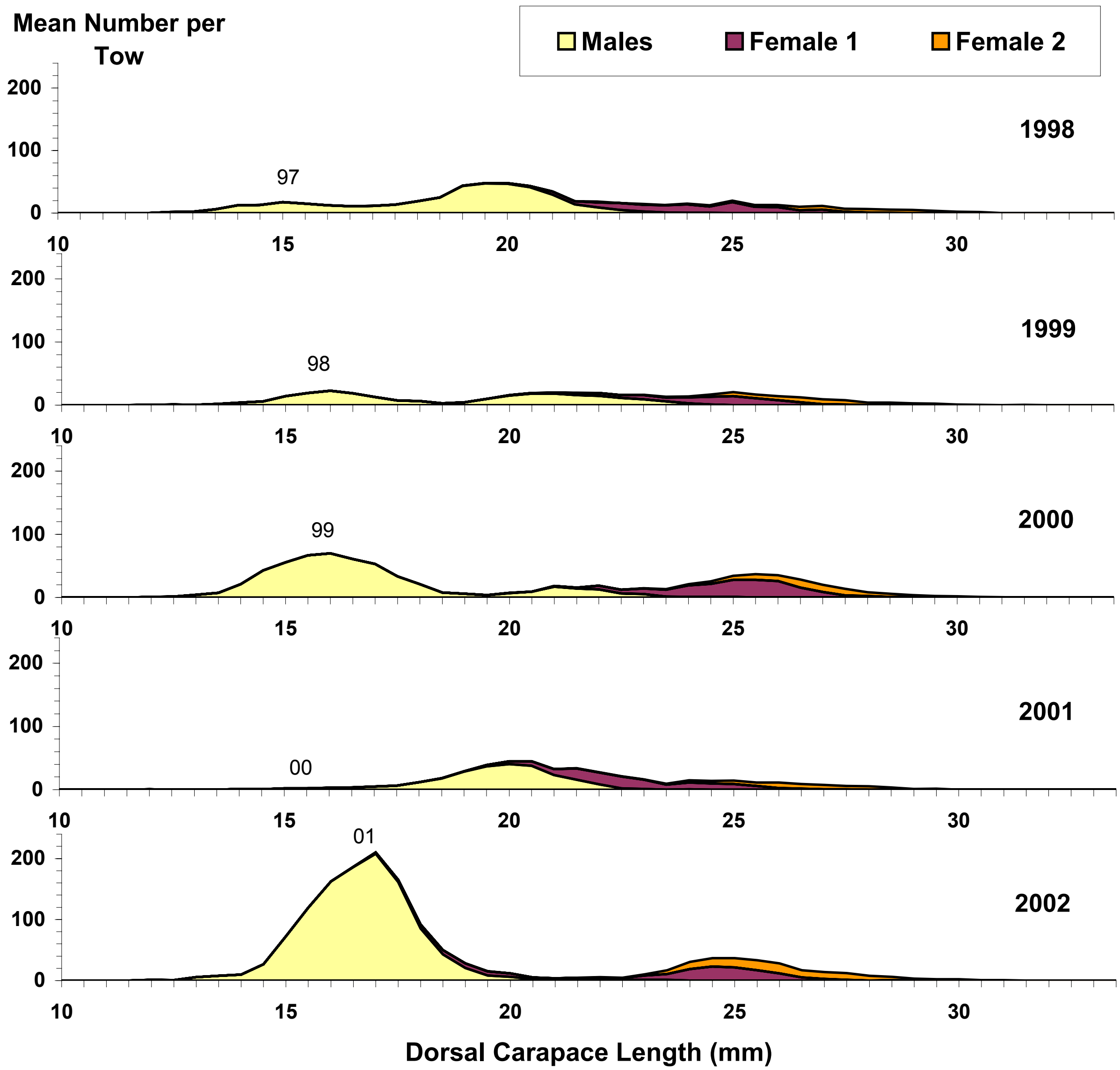


Figure 10. Fishing mortality, abundance, and biomass of Gulf of Maine northern shrimp, least squares estimates, bootstrapped means, and 80% confidence intervals.

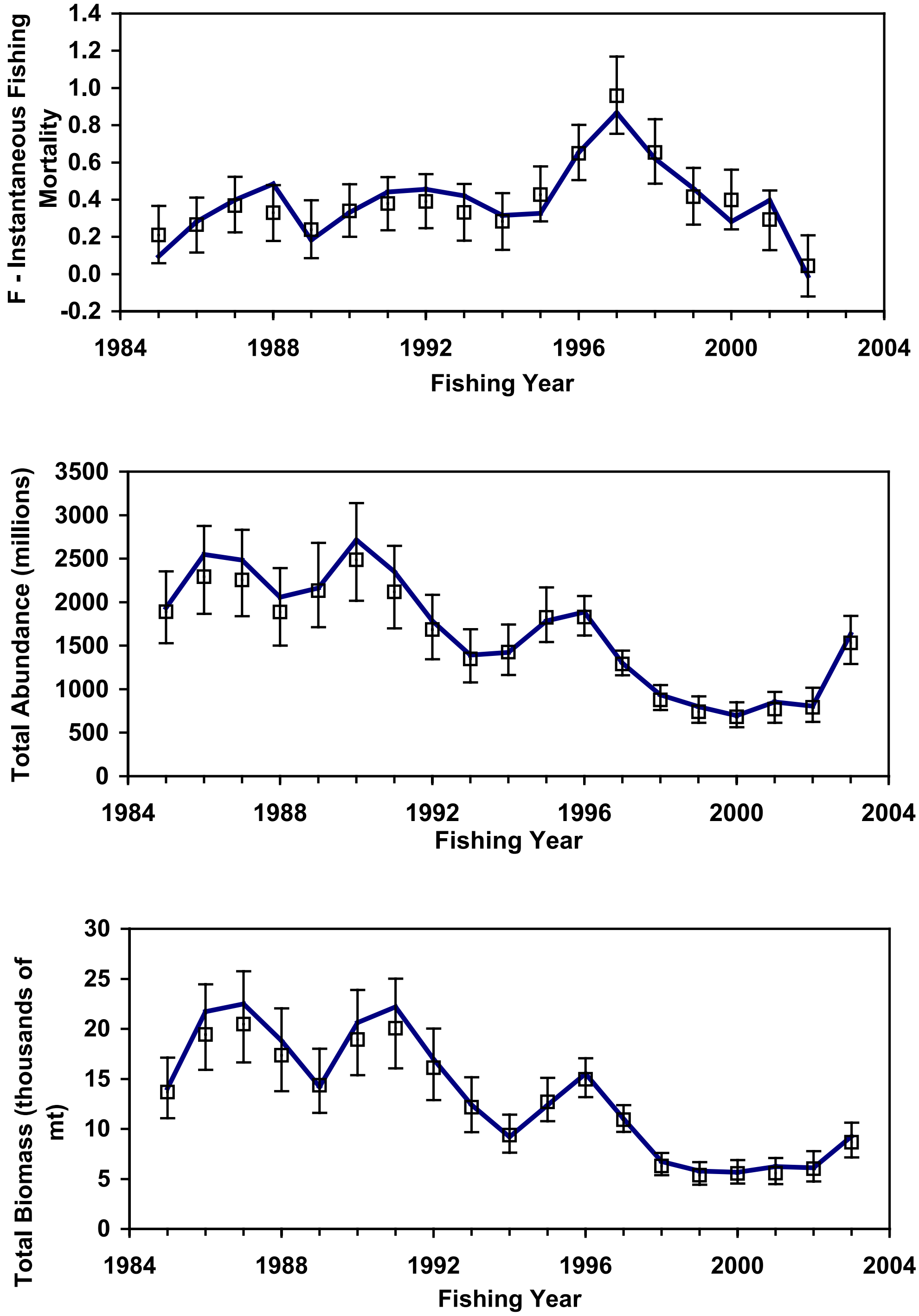


Figure 10. continued

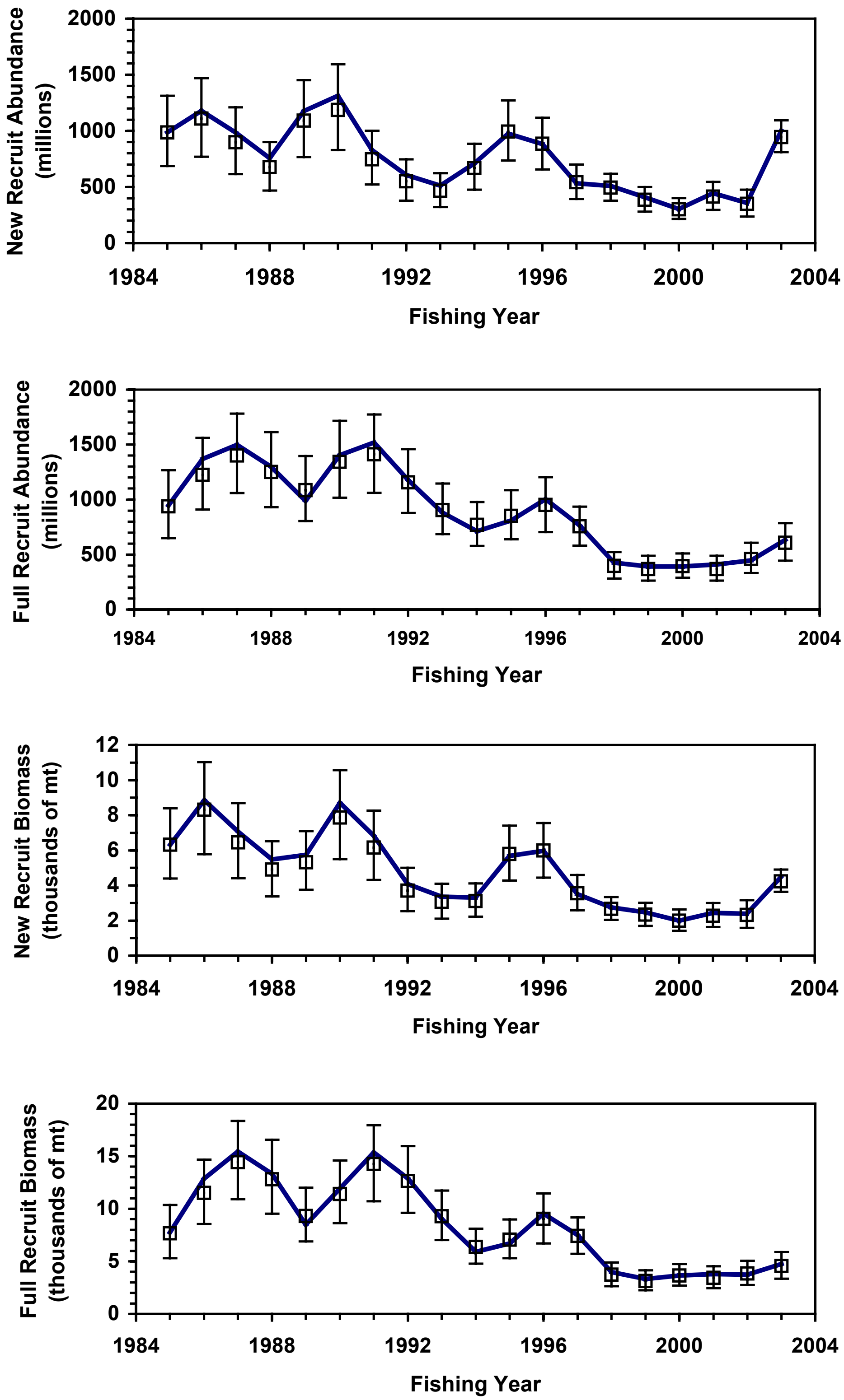


Figure 11. Collie-Sissenwine Analysis Input Data and Results

Northern Shrimp
using Summer Survey

Survey Year*	Indices of Abundance: Recuits	Indices of Abundance: Full Recruits	Total Catch Millions
1984	447.5580	479.0570	352.7928
1985	619.4560	925.4300	361.1710
1986	533.2920	848.5440	425.2945
1987	482.8980	766.9030	228.4345
1988	459.7550	387.7140	283.6468
1989	701.0930	817.9000	442.4292
1990	511.5210	907.5220	320.2898
1991	374.2770	612.0870	262.4338
1992	313.5950	444.3580	194.7883
1993	410.1960	320.7500	270.4058
1994	368.5900	364.3020	615.3185
1995	485.7860	653.3320	799.3678
1996	257.6520	348.6160	718.4332
1997	257.2980	267.1010	373.6801
1998	217.1340	226.6420	215.1221
1999	137.3900	174.6070	209.2793
2000	276.2810	288.1930	141.4937
2001	171.8090	196.3560	38.6779
2002	550.6000	372.9300	

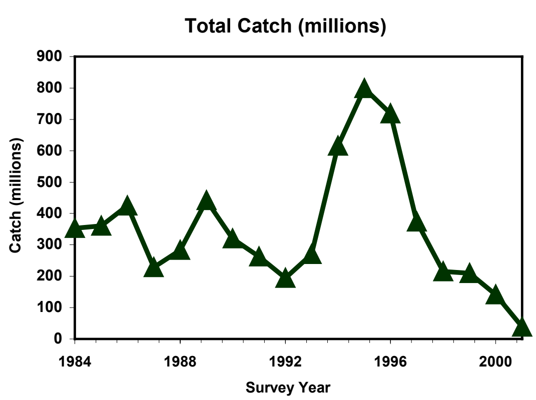
* Survey Year Data are applied to the following Fishing Year

Input File Name	R2002.dat
Tuning Dataset	Survey
Time of Survey (yr)	0
Time of Catch (yr)	0.5
Natural Mortality Rate	0.25
Relative Catchability: Recruits to Full Recruits s_r	0.7 - 1.0
Catchability Estimate and CV	0.550 0.16
Average Partial Recruitment Rate to Fishery	0.63
Average Z_all sizes (1999-2001)	0.59
Average Z_all sizes (2000-2001)	0.44

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 2001

Survey Year*	Stock Size Estimates millions at time of Survey: Recruits	Stock Size Estimates millions at time of Survey: Full Recruits	Total Mortality Z all sizes	Fishing Mortality All Sizes
1984	986.8	947.3	0.34	0.09
1985	1179.3	1369.9	0.53	0.28
1986	984.7	1497.6	0.65	0.40
1987	757.5	1298.8	0.73	0.48
1988	1176.6	987.2	0.43	0.18
1989	1313.2	1402.9	0.58	0.33
1990	829.4	1519.4	0.69	0.44
1991	608.2	1177.1	0.71	0.46
1992	511.5	881.3	0.67	0.42
1993	711.4	712.6	0.57	0.32
1994	975.1	808.6	0.58	0.33
1995	883.4	1002.7	0.90	0.65
1996	534.0	764.1	1.12	0.87
1997	510.5	424.6	0.87	0.62
1998	408.2	391.5	0.71	0.46
1999	303.4	392.8	0.53	0.28
2000	445.1	409.4	0.65	0.40
2001	357.9	447.9	0.24	-0.01
2002	1000.6	634.2		

* Survey Year Data are applied to the following Fishing Year



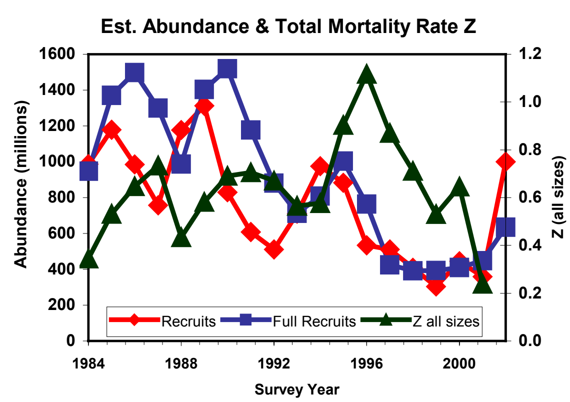


Figure 12. Estimates of fishing mortality (above) and stock biomass (below) for northern shrimp from Collie-Sissenwine analysis and surplus production modeling.

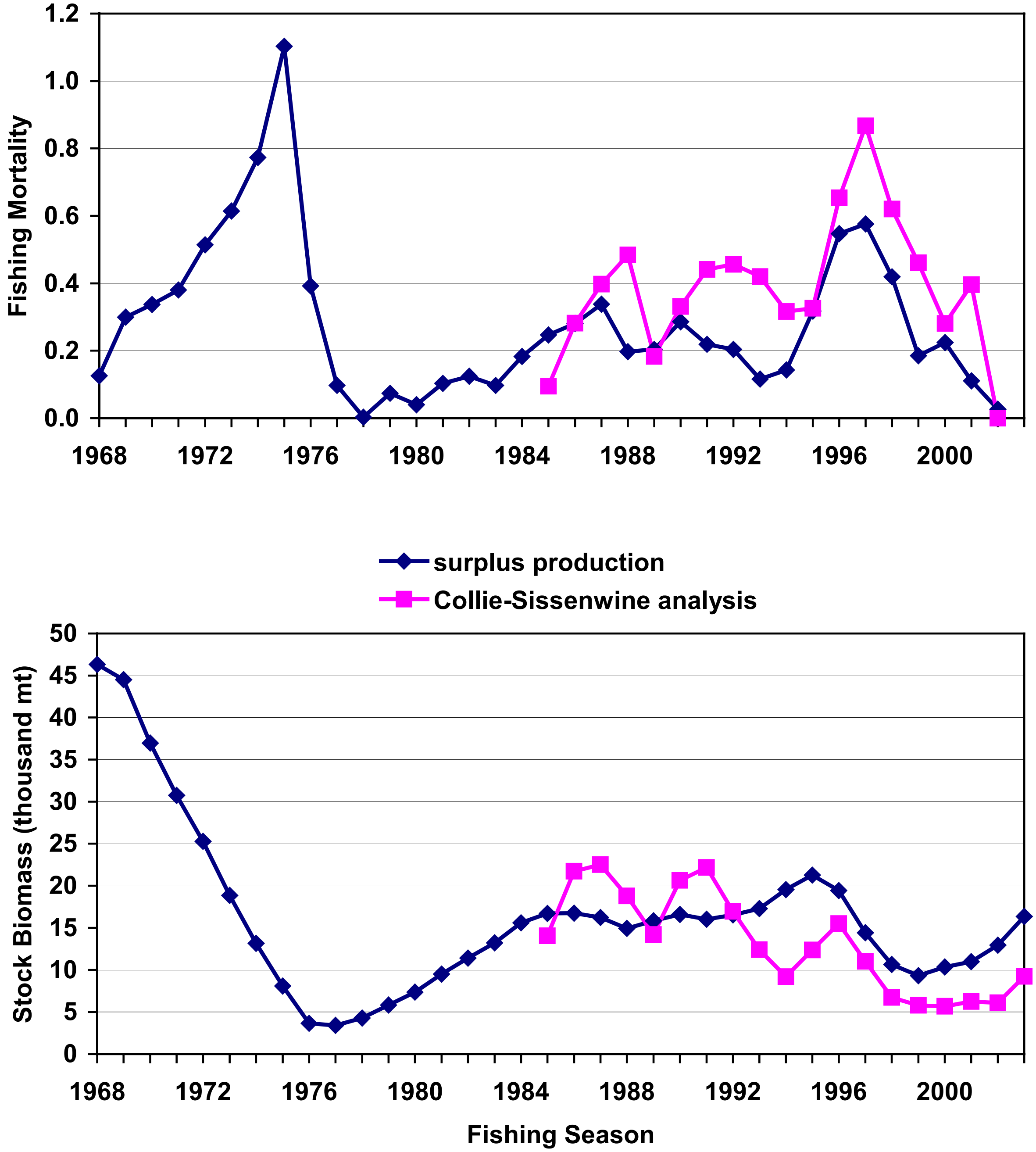
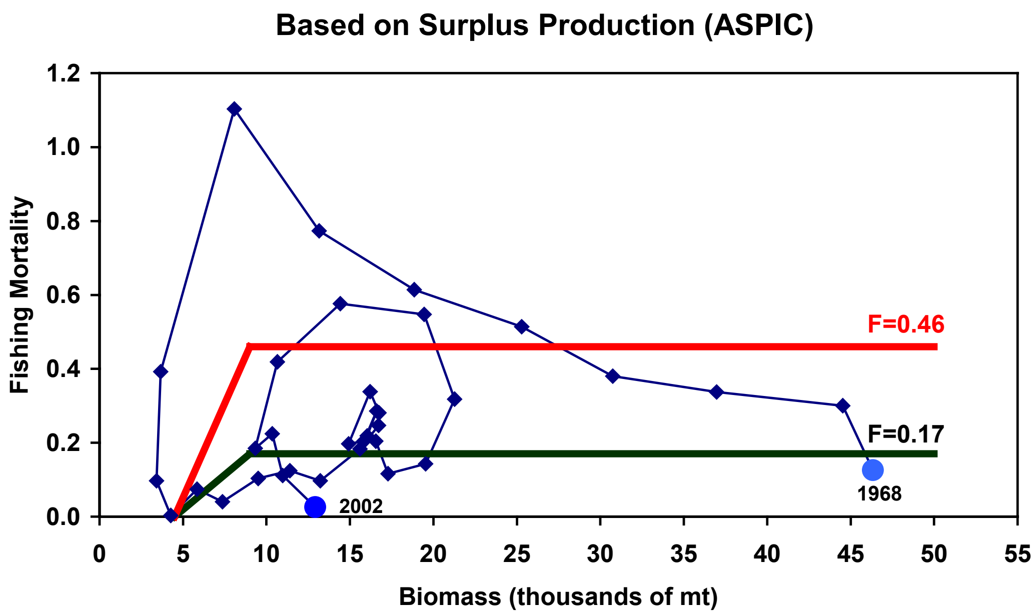


Figure 13. Biomass dynamics of the Gulf of Maine northern shrimp fishery, from surplus production (above) and Collie-Sissenwine (below) analyses, with possible fishing mortality and biomass reference points.



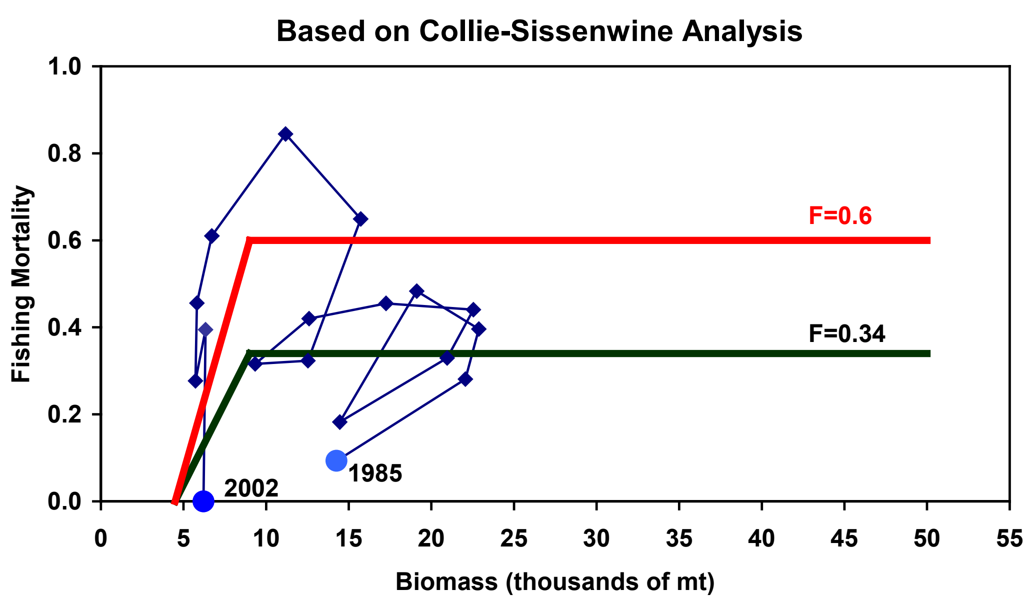
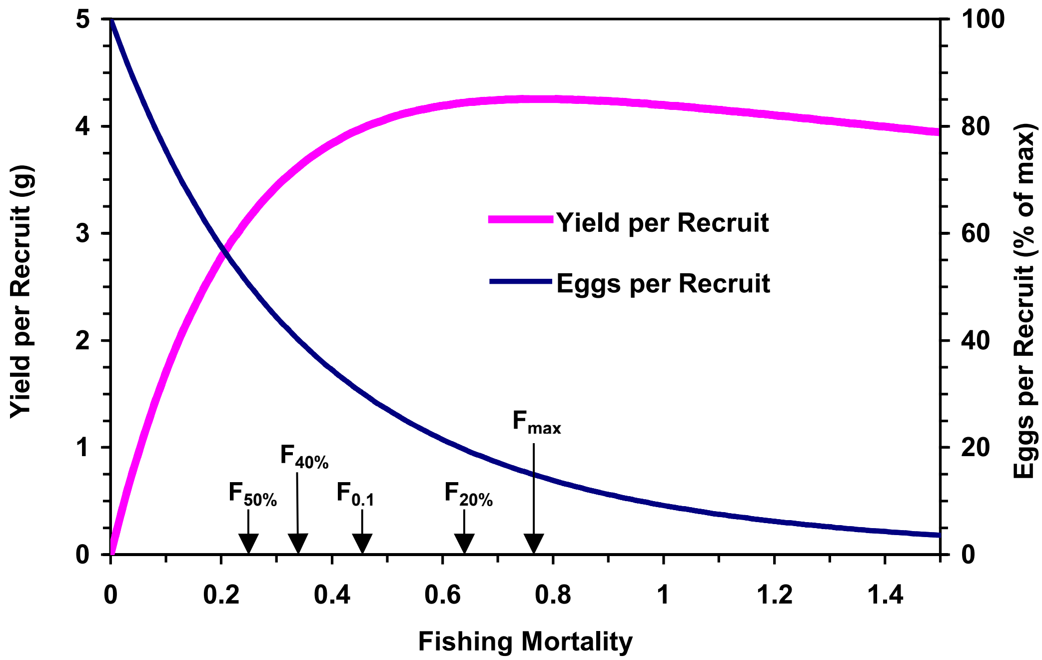


Figure 14. Yield and egg production per recruit.



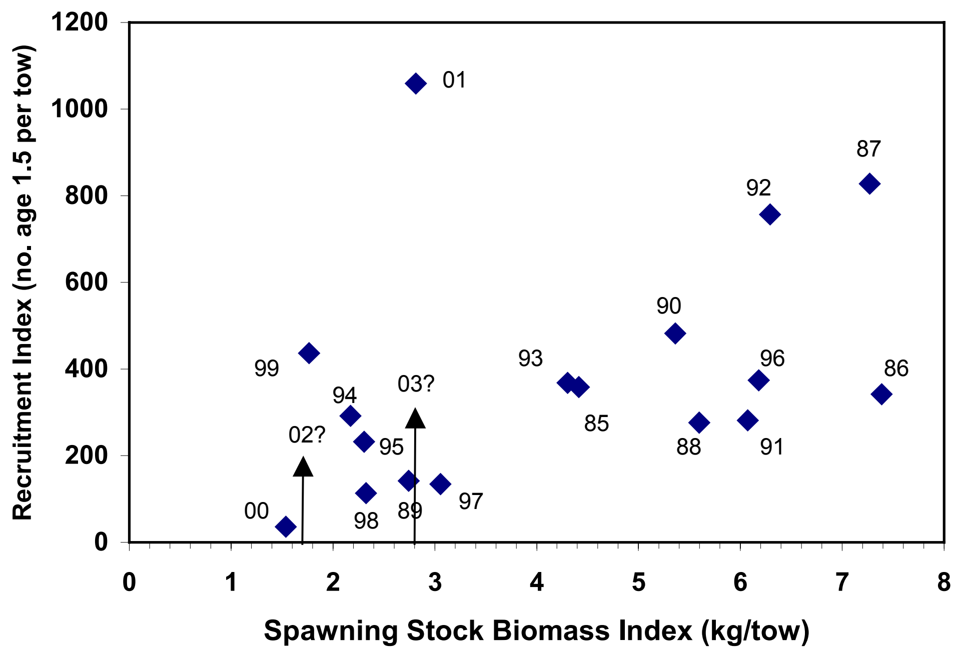


Figure 15. Relationship between summer survey index of Gulf of Maine female shrimp biomass the summer before spawning to age 1.5 abundance two years later. Two-digit numbers indicate the assumed age 1.5 year class.