ASSESSMENT REPORT

FOR

GULF OF MAINE NORTHERN SHRIMP -- 2000

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

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INTRODUCTION

The Gulf of Maine fishery for northern shrimp (*Pandalus borealis*) 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 the summer of 2001. 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.

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.

The Northern Shrimp Section, at its 1999 fall meeting, approved a 51 day season that began January 17, 2000 and ended March 15, 2000. This is the third year days available to the fishery has been reduced in recent years, with prior years showing a steady increase (90 opportunity days in 1999, 105 days in 1998 versus 156 days in 1997, 152 days in 1996, 128 days in 1995, and 122 days in 1994). 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 2000 stock assessment. Analyses and recommendations are based on: 1) research vessel survey data collected by the Committee during summer and by 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, the DeLury, 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 (t) during 1969-1972 to about 400 t 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 t by 1987. Landings ranged from 2,300-4,400 t between 1988-1994. The 1995 season showed a dramatic rise to 6,500 t. The 1996 season saw a further rise in landings to 9,200 t, the highest since 1973. In 1997 the landings declined to 7,200, and the decline continued in 1998 to 4,174 t and in 1999 to 1,816 t. Landings increased slightly to 2,390 t in 2000. The 2000 season of 51 allowable fishing days was the shortest in recent history (Table 2).

Maine landed 87% (2,067 t) of the 2000 season total while New Hampshire and Massachusetts landed 9% (212 t) and 5% (110 t), respectively. This proportional distribution of landings by state has been generally consistent over the past several years. (Table 1, Figure 1). Like past years, in 2000 the months of January and February yielded the highest percentages of the catch, while March exhibited the lowest (Table 2).

Size Composition of Landings

Size composition data (Figure 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 t (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. The 1999 season showed low landings due to very poor recruitment in 1994 and 1995, and only average recruitment in 1996.

Length frequencies obtained from dockside sampling in Maine (Figure 2), New Hampshire and Massachusetts (Figure 3) during the 2000 season showed that the sampled catch consisted primarily of (assumed) age 3+ females having a mid-dorsal carapace length of 22.5 mm and greater, reflecting a capture of the 1996 year class. Relatively low catches of males and immature females were landed throughout the season from the 1998 and 1997 year classes respectively. The large proportion of females landed translated into the same number of shrimp caught during the 2000 season as in the 1999 season, with a higher weight of total landings. The late start to the season protected some females through egg drop in January. By February, most females had dropped their eggs in Massachusetts, while the majority of females in Maine dropped them by March.

Effort and Distribution of Effort

Effort in the northern shrimp fishery (measured by numbers of trips in which shrimp gear is used) has increased considerably since the late 1970's. Most fishing is conducted by otter trawls, although traps are also employed off the central Maine coast. Maine trapping operations accounted for between 4% to 8% of the state's total number of trips from 1987 to 1994. The total number of trawl trips in the fishery peaked at 12,300 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 in 1999, and 3,382 in 2000 (Table 3). While approximately 310 vessels participated in the shrimp fishery in 1997 and 260 vessels in 1998, there were about 238 participants in the 1999 fishery and many of these only fished for a few days. 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 the 33 vessels in 1998 to 27 in 1999. Vessel information for the 2000 season has not been analyzed yet.

Prior to 1994, effort (numbers of trips by state and month) was estimated from landings data collected from dealers and landings per trip information from dockside interviews of vessel captains. In the spring of 1994, a logbook reporting system replaced the collection of effort information from interviews. Since 1995, landings per trip (LPUE) from vessel trip reports have been expanded to total landings from the dealer weighouts:

$$\text{Effort} = \frac{\text{Landings}}{\text{LPUE}}$$

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, effort estimates reported here for recent years should be considered extremely preliminary. Logbooks (VTR's) were required of every shrimp fisherman for the first time in the 2000 fishery. Thus measuring the distribution of effort will become much more accurate in the future.

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.

Seasonal trends in distribution of effort have been evaluated over the past 8 years. The relative magnitude of offshore fishing effort has varied in earlier years (1990-1993), reflecting seasonal movements of mature females (inshore in early winter and offshore following larval hatching),

but also reflect fishermen's choices for fishing on concentrations of shrimp. 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 1997 fishing season saw offshore fishing continue throughout the year with 44% of the sampled trips in January and February coming from 55 F or deeper and almost all the trips from the other months coming from offshore. The 1996 and 1998 season's fishing pattern mirrored that of 1994. 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 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.

Catch per Unit Effort

Catch per unit effort (CPUE) indices have been developed from NMFS interview data (1983-1994) and logbook data (1995-2000) and are measures of resource abundance and availability (Figure 5). Pounds landed per trip increased from 735 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 1,074 pounds. The 1995, 1996 and 1997 CPUEs, from logbooks, rose sharply to 1,362 pounds in 1995, rose again to 1,713 in 1996 and declined to 1,455 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 1,557 pounds per trip. A trip may be a misleading unit of effort,

because estimates from both interviews and logbooks include multiple day trips in the spring and there may be an increasing number of such trips in recent years.

More precise CPUE indices (pounds landed per hour fished), have also been developed for both inshore (<55F) and offshore (>55F) areas using information collected by Maine's and New Hampshire's port sampling programs. The inshore CPUE in 2000 increased to 288 pounds per hour towing compared to CPUEs of 158 in 1998 and 1999 after dropping from a high of 304 in 1996 and 206 in 1997. The offshore CPUE dropped steadily from 203 pounds in 1996 to 192 pounds in 1997, 151 pounds in 1998 and 146 pounds in 1999, then jumped to 337 pounds in 2000. The total CPUE in 2000 was 292, nearly double the 1998 and 1999 values of 154 and 152 respectively. This value was the highest on record, exceeding the 1996 value of 251, and equivalent to or exceeding peak years during previous periods when there were strong year classes in the fishery.

The CPUE from the port sampling interviews agrees well with the catch per trip data from logbooks (see text table below). While occasional trips with CPUE in excess of 300 pounds were recorded in 1994 and were considered to be high catch rates, several trips with CPUE in excess of 600 pounds per hour towing were recorded in 1995 and several trips in excess of 700 pounds per hour fished were recorded in 1996. One harvester reported a CPUE of over 1000 lbs./hr for one of his fishing days. In 1997, the sampled catch exceeded 600 pounds per hour once, showed 10 trips over 400 and 22 trips over 300. The five highest catch rates in the 1998 sampled catch were 485, 408, 349, 346 and 345 pounds per hour towing while in 1999 the CPUE exceeded 300 pounds per hour towing only once. The port sampling interviews for Maine for January 2000 gave 1 trip with a CPUE of over 1000 lbs./hr, 5 more that exceeded 700, and 7 more over 400 lbs./hr, out of 23 total interviews. The CPUE declined in February, with no trips over 700, and 3 trips over 400, out of 31 total. The 3 interviews made in Maine in March all had a CPUE of about 100 lbs./hr.

ME/NH CPUE in lbs./hour towed, from port sampling. Catch (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	1,074
1995	172	205	193	1,362
1996	340	203	251	1,713
1997	206	192	194	1,455
1998	158	151	154	1,317
1999	159	146	152	1,067
2000	288	337	292	1,557

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 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 2000 summer survey cruise are plotted in Figure 6. 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, with peaks in 1986, 1990 and 1994, reflecting 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 with passage of the 1992 year class through the fishery, the index rose sharply in 1998, reflecting recruitment of the 1996 year class at age 2 (trends for the NEFSC spring survey index are similar). This year class was reported to be of above average size in the 1997 and 1998

assessments. This year class predominated in NEFSC 1998 autumn survey catches, with catches from other year classes being minor. The 1999 NEFSC fall survey index remained high, indicating remaining strength in the 1996 year class.

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the state-federal survey from 1984-2000 are given in Table 4, length-frequencies by cruise are provided in Figure 9. Table 4 provides indices for all size/age groups, indices for age 1.5 animals and indices for shrimp >22 mm mid-dorsal carapace length. The catch per tow in numbers of 1.5-year old shrimp (the total number in the first size modes in Figure 9) represents a recruitment index which, although the shrimp are not fully recruited to the survey gear, appears sufficient as a preliminary estimate of year-class strength. 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.

Again, all of these indices have shown peaks which reflect recruitment of the strong 1982, 1987 and 1992 year-classes (Table 4, Figure 8). The 1992 year class observed at (assumed) age 1 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 appears comparable to the 1993 year class (Table 4, Figure 9) with this exception, recruitment since 1993 has been poor, with the 1997 and 1998 year classes being among the weakest in the time series (Figure 9). Thus, up through 1999 the only significant source of potential recruitment to the future winter fisheries was that provided by the 1996 year class. The 1996 year class dominated landings throughout much of the 1999 fishing year. The 1999 year class, seen for the first time in the summer 2000 survey, is comparable to the 1996 year class and thus is larger than recent year classes. The 2001 fishing year will be predominantly on the remainder of the 1997 year class and on the relatively weak 1996 year class. The larger 1999 year class will barely be within the selectivity of the fishing gear and so only a small proportion of this class will be caught in 2001.

Since 1995, there has been a consistent downward trend in the total number and biomass indices, with 1999 values being at or near the lowest observed. The 2000 index of harvestable biomass increased to 3.2 kg per tow from 1.9 kg per tow on the transformed scale. This increase likely reflects the reduced exploitation in the last two fishing years. The index is still well below historical levels. The total number per tow doubled from 398 in 1999 to 807 in 2000, reflecting primarily the recruitment from the 1999 year class. While we are encouraged by the 1999 year class strength, we feel resource conditions remain poor for the 2001 fishing year as all indices are well below historical levels.

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: modified DeLury analysis tracks the removals of shrimp using summer survey indices of recruits and fully-recruited shrimp scaled to total catch in numbers (from dealers' reported landings and port sampling); 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 on what levels of fishing are most productive and sustainable.

DeLury 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 decreased to 0.4 billion at the end of the 1999 season, the lowest level in the time series. Recruitment in 2000 increased to 0.6 billion but remained below the time series average. 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 0.4 billion in 1999 and increased slightly to 0.5 billion in the current year. Total stock biomass estimates averaged about 14,000 mt, with peaks at over 22,000 mt before the 1985, 1986, and 1991 seasons, and a decrease to a time series low of 5,700 mt in 1998. Total stock biomass has increased slightly over the last two years to its current value of 7,400 mt (Figures 10, 11).

Annual estimates of fishing mortality averaged 0.34 (26% exploitation) for the 1985 to 1995 fishing seasons, peaked at 0.85 (52% exploitation) in the 1997 season and decreased to 0.23 (18% exploitation) in the 2000 season (Table 5; Figures 10, 11). The recent pattern in F reflects the pattern in nominal fishing effort (Figure 5). Precision of DeLury estimates was assessed by "bootstrap" analysis, in which survey measurement errors were randomly shuffled 200 times to provide simulated replications of the model. Bootstrap results suggest that estimates of abundance, biomass and mortality were relatively precise. A retrospective analysis showed that the model overestimated F and underestimated biomass in 1999.

An alternative method of estimating stock size and F was used to corroborate results from DeLury analysis. A surplus production model was fit to seasonal catch and survey biomass indices from 1968 to 1999 (summarized in Table 6). Estimates of F from the biomass dynamics model generally confirm the pattern of estimates from the DeLury model; F in 2000 (F = 0.21) has decreased from a peak of 0.55 in 1997 but is up slightly from 1999. The starting biomass in 1999 (9,861 mt) was the lowest since 1980 (Figures 12 and 13) and has increased to 10,090 mt in 2000.

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, the stock was not replacing itself when spawning potential was reduced to less than 20% of maximum, and the stock collapsed when egg production was reduced further. Reproductive success for Gulf of Maine northern shrimp is a function of population fecundity and spring seawater temperature (Figure 14). 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).

SUMMARY AND CONCLUSIONS

The back-to-back strong 1992 year class and moderately strong 1993 year class produced the bulge in the catch in the northern shrimp fishery between 1994 and 1998. This has not occurred since the late 1960's. These strong year classes have now passed out of the fishery.

Landings in 2000, 2389 t, were up from 1999, 1816 t, but were still down considerably from the 1998 landings and reflect a high initial CPUE and a season of only 51 days. While it was felt that the low landings in 1999 were caused by several environmental, biological and market factors and thus might not have been a clear indicator of the condition of the stock, likewise, the 2000 landings are believed to be the result of several factors. While commercial CPUE in 1999 continued a steady decline from the 1996 level of 1713 lbs./trip to 1067 lbs./trip, commercial CPUE in 2000, 1557 lbs./trip, was the second highest in the time series behind 1996. The number of trips in 2000, 3382, was lower than in 1999, 3811, was dramatically lower than the high in 1996 of 11,791, and reflected the short season.

Short-term commercial prospects are reasonably favorable even though abundance remains relatively low. The improved prospect for the coming season is due to the average sized 1996 year class being second year females this year and the low landings in 1999 having left a good share of them in the water.

Indices of the status of the stock are taken from the commercial fishery, i.e. catch and CPUE and from fishery independent resource surveys, i.e. NEFSC spring and fall bottom trawl surveys, state-federal summer shrimp survey. The catch in 2000 was the third lowest since 1983 and reflects primarily the short fishing season of 51 days. The fishery's CPUE of 1557 pounds per trip from logbook and weighout data is the second highest in the series since 1991. The ME-NH season average CPUE of 292 pounds per hour towing from port sampling interview data is the highest in the data series from 1991. This value is high primarily due to the very high CPUE's in January. These may have been caused by the delayed start of the fishery, the predominance of the shrimp biomass being in the 1996 year class and a possible push ashore from warm bottom water offshore.

The NEFSC spring survey showed an increase in catch per tow in 1998, but a decrease to a relatively low number in 1999. The NEFSC fall survey index increased in 1998 and remained high in 1999. Both surveys tend to show a one-year-duration spike in catch per tow for stronger year classes of shrimp around age two or three. With the passage of the 1996 year class through that age group, the increases in 1998 in these two survey indices are normal. The fact that the fall index remained high in 1999 is not normal and indicates that the 1996 year class may be stronger than estimated. The state-federal summer shrimp survey in 2000 showed improvement over the record lows in 1999 and was punctuated by the appearance of a moderately strong 1999 year class at age 1.5. The abundance index was up to 807 shrimp/tow from 398 in 1999, the biomass index was up to 6.4 kg/tow from 5.8 in 1999, the recruitment index (age 1.5) was up to 382 shrimp/tow from 100 in 1999 and the harvestable biomass index was up to 3.2 kg/tow from 1.9 in 1999. While these indices are still not very good, they represent a turnaround in the steady decline seen since 1996.

Analytical methods mirror the results of the individual survey indices and catch records, in that the DeLury model shows an F of 0.23, down from 0.50 for 1999 and this low F level may allow a rebuilding of the stock. The model also shows a higher biomass, 7397 t in 2001 and gives a higher biomass for 1999, 6004 t, than it did in last year's run, 5019 t. The surplus production model shows a fairly low F and an improving biomass in 2001. The model is suitable for

indicating long term trends, but values of F and B from individual years should not be used as accurate estimates. Yield per recruit analysis shows an Fmax of 0.77 and an F0.1 of 0.46. The F of 0.23 for the 2000 fishery is much lower than F0.1, a commonly accepted upper limit for F (Table 7). The eggs per recruit model shows the 1999 F to be very close to F50%, considered to be a level conducive to rebuilding the stock. The committee feels that F should be kept near 0.25 (F50%), an admittedly arbitrary rebuilding level of harvest. A fishing mortality of 0.34, which is equal to F40% and the 11 year mean recommended by the SARC review for sustainable harvest, is not as likely to allow the stock to recover from its current low level.

RECOMMENDATION

The Northern Shrimp Technical Committee bases its recommendation to the Section on the biology of the species and the opportunity for improving resource conditions in the future.

The Committee is encouraged that the sharp reduction in landings over the last two seasons has resulted in a relatively low F and a stabilization of the population abundance. Owing to the small population increase that has occurred, the Committee recommends that the Section allow a modest increase in landings during the 2000-2001 fishing season as compared to last year's landings. This will allow F to remain low and provide increased probability of stock rebuilding. The stock remains at a low level (7,400 mt) relative to the biomass present during the 1980's and early 1990's (average 1985-1995 biomass = 16,600 mt) and recruitment continues to be below the time series average.

Exploitable biomass has increased about 21% since last season. Thus, if F were calculated on biomass, landings of 21% greater would maintain F at the rebuilding target of about 0.25 for the 2000-2001 fishing season. However, because the average size of shrimp landed this season is likely to be smaller (recent (1995-2000) average size of 10.56 g/individual versus lasts year's average of 11.41 g/individual), landings must be adjusted by this amount (about 7%) since F is calculated based on number of individuals removed from the population rather than weight. An increase in landings of 14% may result in an F about the same as last year (0.23). The Technical

Committee recommends that the resulting figure, 2850 mt, be the upper limit for landings in the 2000-2001 fishing year.

The Technical Committee recommends a 61-day season for the upcoming fishing year. This is a 20% increase from last season and will likely result in a modest increase in landings. From a biological viewpoint, the 2000 season provided increased benefit to the stock by controlling landings, providing the opportunity for egg drop by some individuals and by minimizing the catch of smaller individuals. The Committee encourages the Section to use this season as a base for formulating the upcoming season.

The Committee has no recommendation concerning the placement of the additional ten days, recognizing that applying all days at the beginning of the season will impact larval production and applying days at the end of the fishery may cause the harvest of smaller shrimp resulting in a higher F and an impact on future yield.

The Technical Committee notes the uncertainty in the estimates of F and stock abundance associated with the terminal years of the DeLury model. There is also considerable uncertainty in projecting the exploitable biomass at 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 setting management options as estimates of both F and stock abundance are subject to change in both directions, i.e., these parameters may be over- or underestimated in any given year. In addition, while the 1999 year class appears strong, the 1997 and 1998 year classes remain below average. These weaker year classes will enter the fishery over the next two seasons and therefore stock rebuilding may slow or cease if landings are allowed to rise sharply.

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Table 1. Commercial landings (mt) of northern shrimp in the western Gulf of Maine, 1958-2000.

Year	Maine		NH		Mass		Total	
1958	2.3		0.0		0.0		2.3	
1959	5.4		0.0		2.3		7.7	
1960	40.4		0.0		0.5		40.9	
1961	30.4		0.0		0.5		30.9	
1962	159.7		0.0		16.3		176.0	
1963	244.0		0.0		10.4		254.4	
1964	419.4		0.0		3.1		422.5	
1965	947.0		0.0		8.0		955.0	
1966	1,737.8		18.1		10.5		1,766.4	
1967	3,141.1		20.0		10.0		3,171.1	
1968	6,515.0		43.1		51.9		6,610.0	
1969	10,992.9		58.1		1,772.9		12,823.9	
1970	7,712.8		54.4		2,902.1		10,669.3	
1971	8,354.7		50.8		2,723.8		11,129.3	
1972	7,515.6		74.8		3,504.5		11,094.9	
1973	5,476.7		59.9		3,868.2		9,404.8	
1974	4,430.7		36.7		3,477.3		7,944.7	
1975	3,177.0		29.5		2,080.2		5,286.7	
1976	617.2		7.3		397.8		1,022.3	
1977	148.0		2.3		236.9		387.2	
1978	0.0		0.0		0.0		0.0	
1979	32.9		2.3		451.3		486.5	
1980	71.4		7.4		260.3		339.1	
1981	528.6		4.5		538.1		1,071.2	
1982	883.2	*(853.3)	32.8	(21.6)	658.5	(655.3)	1,574.5	(1,530.2)
1983	1,022.0	(892.5)	36.5	(46.2)	508.0	(458.4)	1,566.5	(1,397.1)
1984	2,564.7	(2,394.9)	96.8	(30.7)	565.3	(525.1)	3,226.8	(2,950.7)
1985	2,956.9	(2,946.4)	207.4	(216.5)	1,030.6	(968.0)	4,194.9	(4,130.9)
1986	3,407.3	(3,268.2)	191.1	(230.5)	1,085.6	(1,136.3)	4,684.0	(4,635.0)
1987	3,534.2	(3,673.2)	152.5	(157.8)	1,338.7	(1,422.2)	5,025.4	(5,253.2)
1988	2,272.4	(2,257.2)	173.1	(154.5)	631.5	(619.6)	3,077.0	(3,031.3)
1989	2,542.6	(2,384.0)	314.3	(231.5)	749.6	(699.9)	3,606.5	(3,315.4)
1990	2,961.5	(3,236.1)	447.3	(451.2)	993.2	(974.3)	4,402.0	(4,661.6)
1991	2,431.1	(2,488.1)	208.2	(282.2)	727.6	(801.1)	3,366.9	(3,571.4)
1992	2,973.9	(3,054.1)	100.1	(100.0)	291.6	(289.1)	3,365.6	(3,443.6)
1993	1,562.8	(1,492.2)	441.1	(357.4)	300.3	(292.8)	2,304.7	(2,142.9)
1994	2,815.5	(2,239.3)	520.9	(428.0)	374.4	(247.5)	3,710.8	(2,914.8)
1995		(5,022.7)		(764.9)		(678.8)		(6,466.4)
1996		(7,737.0)		(771.0)		(658.0)		(9,166.1)
1997		(6,050.0)		(666.3)		(362.8)		(7,079.1)
1998		(3482.0)		(445.2)		(247.2)		(4,174.4)
1999		(1523.4)		(217.0)		(75.7)		(1,816.1)
2000		**(2,067.3)		**(212.3)		**(109.9)		**(2,389.5)

*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, 1986-2000.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1986 Season*	1st					31st		
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	1st					31st		
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	1st					31st		
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	1st					31st		
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	1st					31st		
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	1st					31st		
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	15th					15th		
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	14th				30th			
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

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1994 Season	15th				15th			
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
1995 Season**	1st				30th			
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**	1st					31st		
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***	1st					27th		
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****	8th					22nd		
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	1,099.1	1,278.8	433.1	281.4	204.7		3,946.7
1999 Season*****	16th					27th		
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	233.5		1,826.1
2000 Season******		17th		15th				
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

* Season extended to June 21.
** One day/week off.
*** Two 5-day and four 4-day blocks off.
**** Dec 8 - May 22, weekends off, Dec 25-31 and Mar 16-31 off.
***** Dec 16 - May27, weekends off, Dec 25 - 31 and Mar 16-31 off.
****** Jan 17 - Mar 15, Sundays off, preliminary data.

Table 3. Distribution of fishing effort (number of trips) in the Gulf of Maine northern shrimp fishery by state and month, 1986-2000.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1986 Season*	1st					31st		
Maine	590	1,309	2,798	831	224	133	68	5,953
Mass.	128	235	225	320	194	133	159	1,394
N.H.	156	163	165	51	3		17	555
Total	874	1,707	3,188	1,202	421	266	244	7,902
1987 Season	1st					31st		
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	1st					31st		
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	1st					31st		
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	1st					31st		
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	1st					31st		
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	15th					15th		
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	14th				30th			
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

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1994 Season	15th				15th			
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**	1st				30th			
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**	1st					31st		
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***	1st					27th		
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****	8th					22nd		
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*****	16th					27th		
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******		17th		15th				
Maine		591	1,944	418				2,953
Mass		17	105	36				158
N.H.		33	170	68				271
Total		641	2,219	522				3,382

* Season extended to June 21.
** One day/week off.
*** Two 5-day and four 4-day blocks off.
**** Dec 8 - May 22, weekends off, Dec 25-31 and Mar 16-31 off.
***** Dec 16 - May27, weekends off, Dec 25 - 31 and Mar 16-31 off.
****** Jan 17 - Mar 15, Sundays off, preliminary data.

Table 4. Stratified mean number per tow* of northern shrimp collected during R/V Gloria Michelle summer surveys 1984-2000.

Untransformed

Year	Total Number	Age-1.5 abundance	>22 mm** abundance	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	2,419	535	1,350	21.0	15.1
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	1551	1,017	19.8	11.6
1998	2,318	405	676	15.1	7.4
1999	1,648	414	719	11.9	7.8
2000	1,844	872	647	11.9	7.2

Ln Transformed

Year	Total Number	Age-1.5 abundance	>22 mm** abundance	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	306	773	14.8	8.6
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	756	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	100	174	5.8	1.9
2000	807	382	283	6.4	3.2

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

Table 5. Summary of results from DeLury analysis of Gulf of Maine shrimp.

Fishing Season	Recruits (millions)	Fully-Recruited (millions)	F(N+R)	Biomass (mt)
1985	1004.002	963.936	0.09	14297
1986	1196.005	1393.824	0.29	22068
1987	988.682	1508.192	0.43	22636
1988	710.21	1265.189	0.45	18177
1989	1204.885	976.236	0.18	14264
1990	1338.667	1423.426	0.33	20981
1991	845.754	1549.751	0.44	22632
1992	619.779	1201.675	0.45	17309
1993	521.327	900.067	0.42	12653
1994	723.571	727.28	0.32	9378
1995	986.713	824.077	0.32	12574
1996	892.87	1019.517	0.65	15738
1997	538.657	775.783	0.85	11154
1998	518.919	435.419	0.61	6875
1999	380.059	404.205	0.44	5729
2000	352.825	395.006	0.23	6004
2001	569.185	460.998		7397
1986-95 avg	914	1177	**0.36**	17267
		1999-00 ave	**0.34**	

Table 6. Summary of results from surplus production analysis of Gulf of Maine northern shrimp 1967-2000

Fishing Season	Input Fall (kg/tow)	Maine (kg/tow)	Summer (kg/tow)	Catch (mt)	Results Biomass (mt)	F	B/Bmsy	F/Fmsy
1967								
1968	3.2	45.8		5708	54160	0.111	2.025	0.6508
1969	2.7	31.2		12140	49100	0.276	1.836	1.62
1970	3.7	40.8		11330	39590	0.318	1.48	1.863
1971	3	9.4		10590	32280	0.365	1.207	2.14
1972	3.3	7		11220	26190	0.498	0.9793	2.922
1973	1.9	7.8		9691	19390	0.597	0.725	3.502
1974	0.8	4.9		8024	13530	0.747	0.5061	4.38
1975	0.9	6.7		6142	8422	1.027	0.315	6.026
1976	0.6	4.8		1387	4081	0.345	0.1526	2.023
1977	0.2	1.6		372	3963	0.083	0.1482	0.4892
1978	0.4	3.2		17	4983	0.003	0.1864	0.0169
1979	0.5	4.4		487	6733	0.064	0.2518	0.3769
1980	0.5	2.7		339	8461	0.035	0.3164	0.2073
1981	1.5	3		1071	10800	0.091	0.404	0.5316
1982	0.3			1530	12870	0.111	0.4813	0.6484
1983	1			1397	14840	0.087	0.5548	0.5109
1984	1.9		10.5	2951	17270	0.166	0.6457	0.9713
1985	1.6		17.7	4131	18370	0.225	0.6868	1.32
1986	2.5		19.6	4635	18350	0.257	0.686	1.505
1987	1.7		14.8	5253	17790	0.307	0.6652	1.799
1988	1.2		12.8	3031	16500	0.179	0.6172	1.048
1989	1.8		17	3315	17420	0.186	0.6515	1.093
1990	2		18.1	4662	18160	0.261	0.6789	1.533
1991	0.9		11.7	3571	17550	0.201	0.6562	1.178
1992	0.6		9.4	3444	18020	0.188	0.674	1.1
1993	1.6		9.1	2143	18690	0.109	0.699	0.6366
1994	2.2		8.7	2915	20790	0.135	0.7776	0.794
1995	1.8		13.3	6466	22260	0.305	0.8325	1.792
1996	1.1		8.8	9166	20160	0.527	0.7537	3.092
1997	1.3		7.7	7079	14980	0.552	0.56	3.241
1998	2.3		6.3	3947	11160	0.398	0.4174	2.334
1999	2.54		5.8	1816	9861	0.175	0.3687	1.027
2000			6.4	2389	10900	0.213	0.4074	1.25
2001					11530		0.4311	
				1998-00 ave		0.262		
				1999-00 ave		0.194		
				1985-95 ave		0.213909		
				1995-98 ave		0.492333		
				1971-74 ave		0.71725		

Table 7. Yield and egg production per recruit of Gulf of Maine northern shrimp.

M = 0.25 Fexample = 0.2

age	length	transition rate	selectivity	N	male N	female N	male catch	female catch	male wt	female wt	yield	fecundity at length	egg production
1	11.17	0	0.033	774	774	0	4	0	0.84	1.24	4	0	0
2	18.43	0	0.23	575	575	0	31	0	3.79	4.82	117	0	0
3	23.5	0.081	0.579	399	367	32	56	0	7.87	9.3	439	1286	41581
4	27.04	0.922	0.799	265	21	244	48	4	12	13.58	635	1876	458156
5	29.51	0.997	0.893	173	0	172	3	35	15.6	17.19	657	2287	393661
6	31.23	1	0.933	112	0	111	0	26	18.5	20.04	523	2574	287027
7	32.43	1	1	71	0	71	0	18	20.72	22.19	399	2775	197299
										total	2773		1377725
										total/rec.	2.773		1378
												%max	57.52

Ref. Point	F	YPR	%EPR
Fmax	0.77	4.2482	14.77
F0.1	0.46	3.9897	29.83
F50%	0.25	3.1449	50
F40%	0.34	3.6213	40
F30%	0.45	3.9676	30
F20%	0.63	4.2087	20
F10%	0.95	4.2111	10

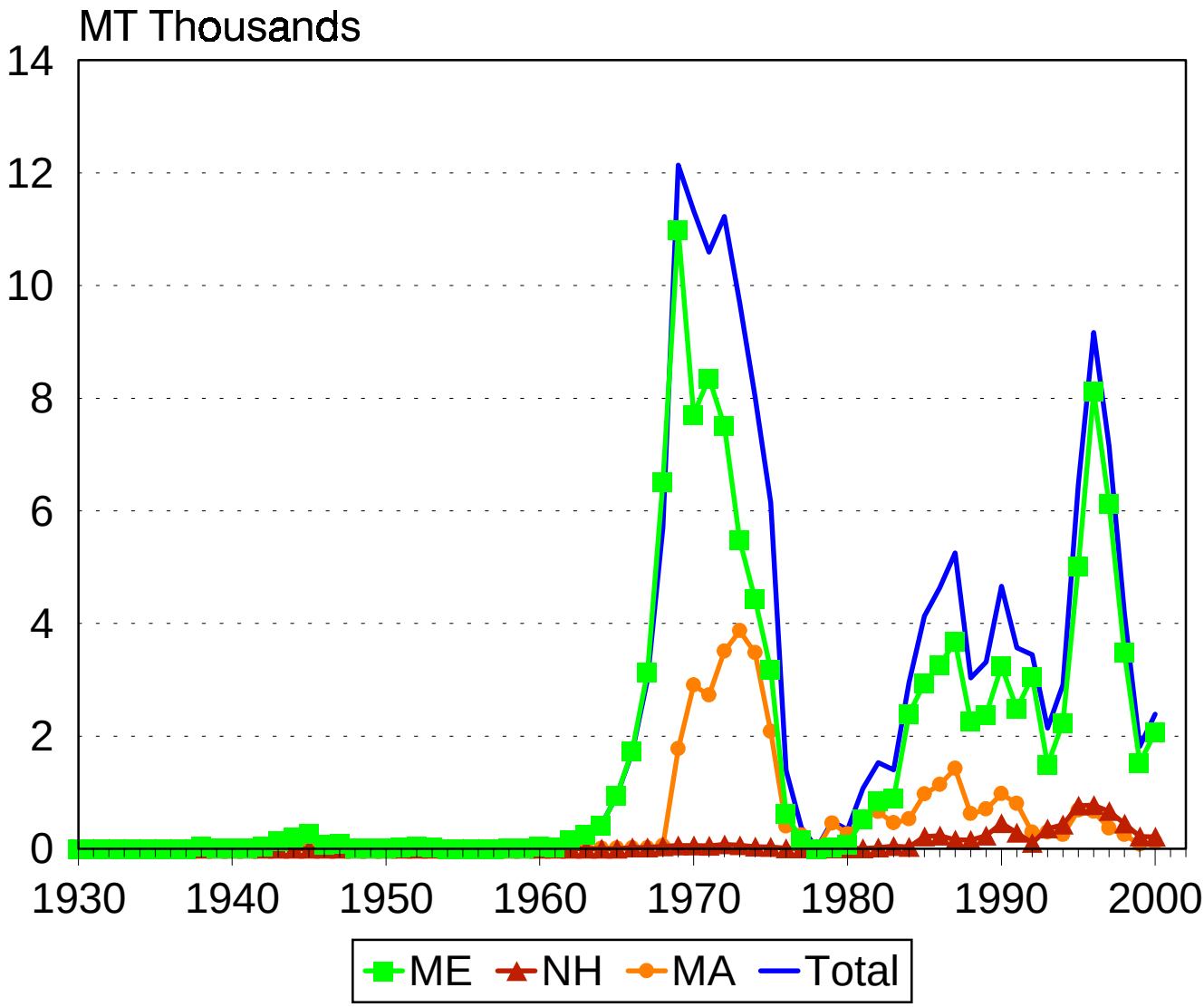


Figure 1. Gulf of Maine northern shrimp landings by fishing season (December to May).

Figure 2. Length frequency distribution derived from biological sampling of Maine commercial shrimp landings during the 2000 season.

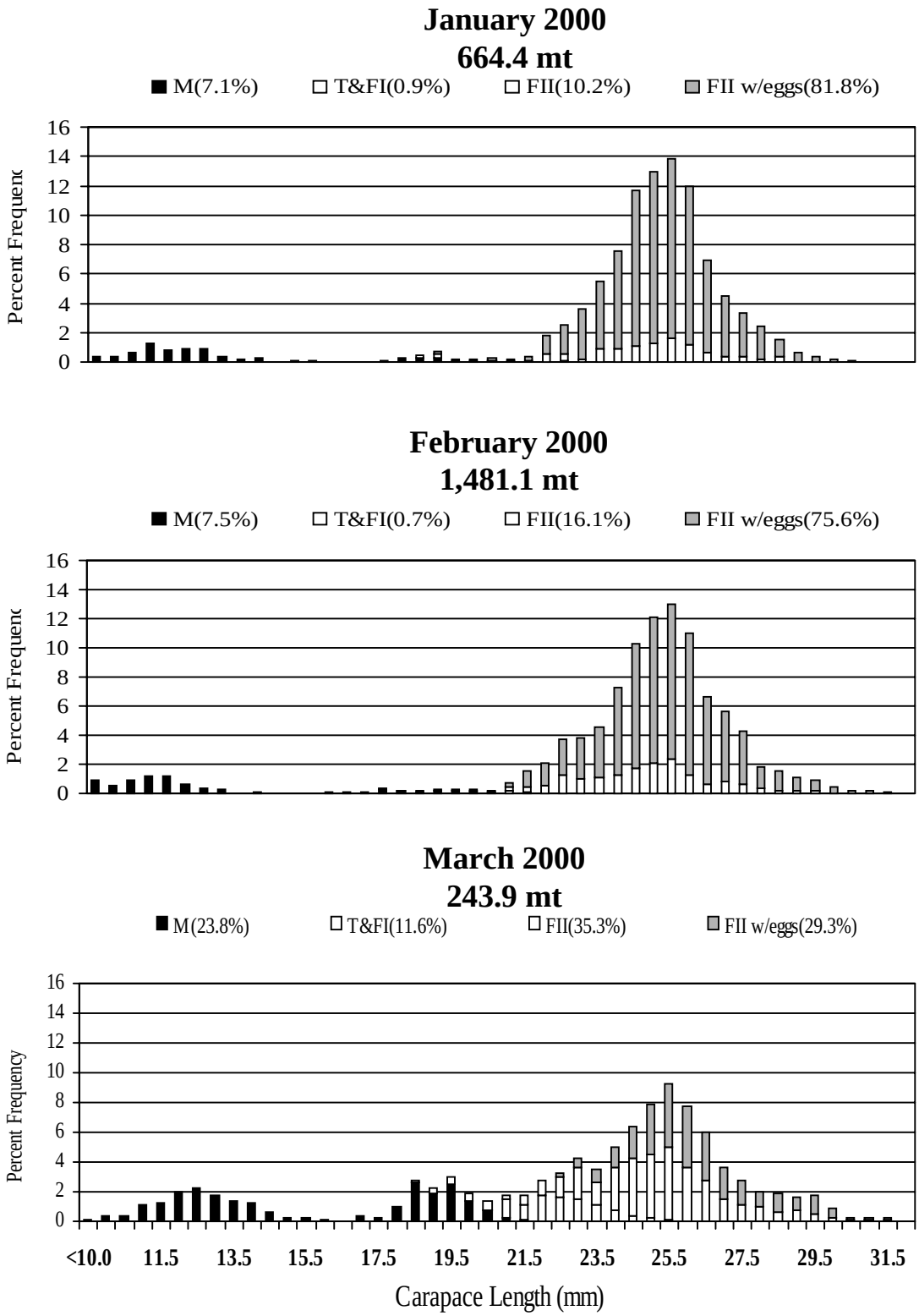
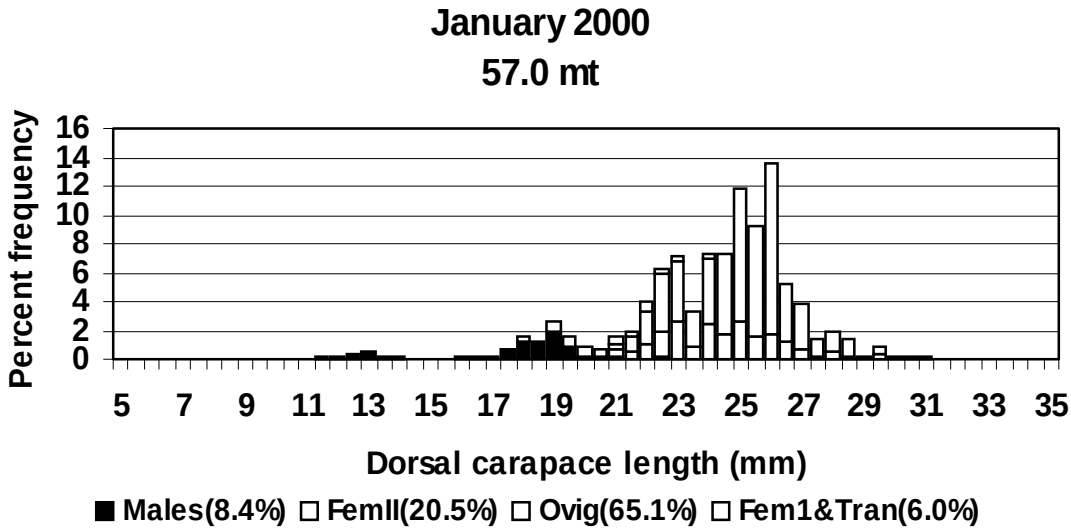
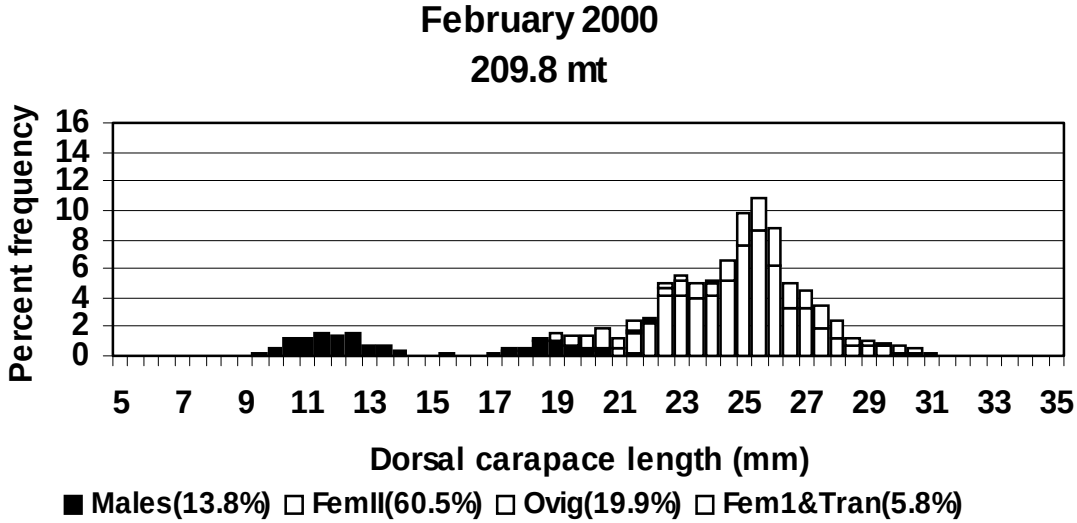
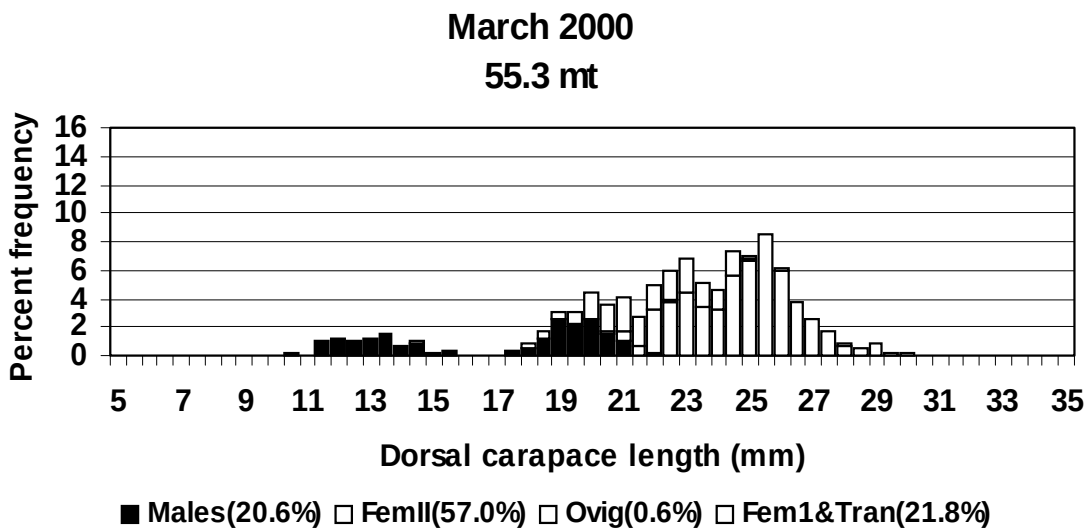


Figure 3. Length frequency distribution derived from biological sampling of Massachusetts and New Hampshire commercial shrimp landings during the 2000 season.







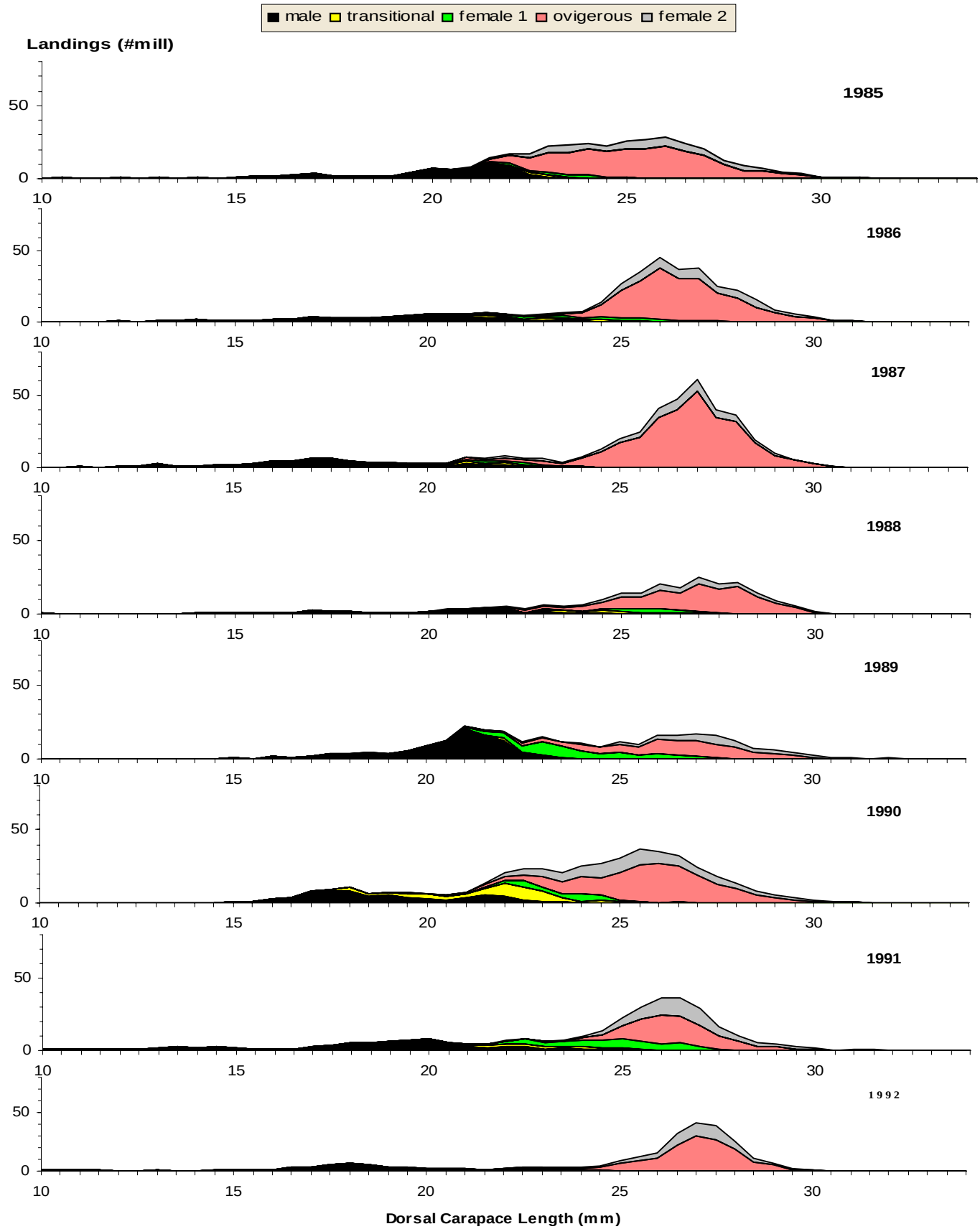


Figure 4. Gulf of Maine northern shrimp landings by length, development stage, and fishing season.

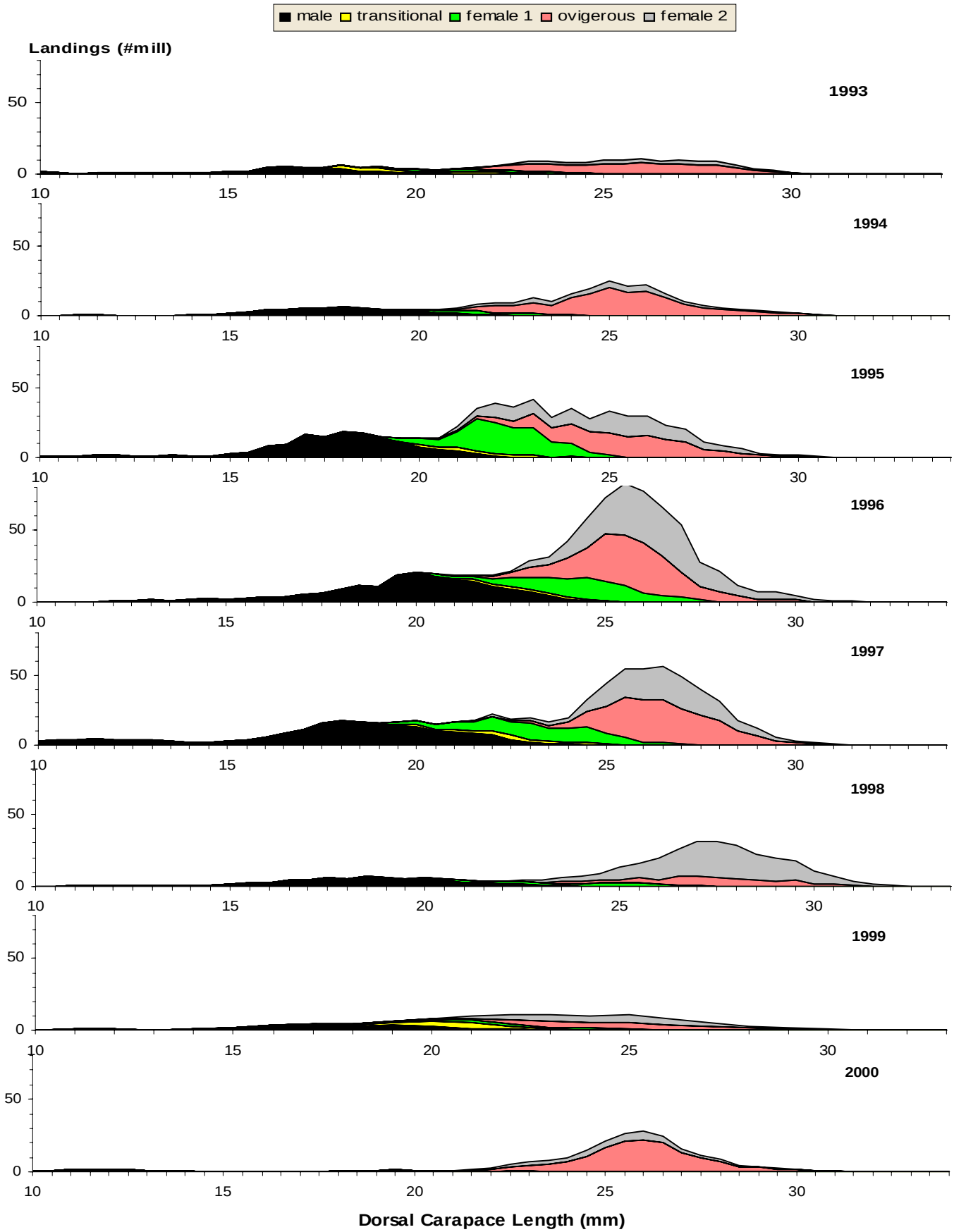


Figure 4. (continued)

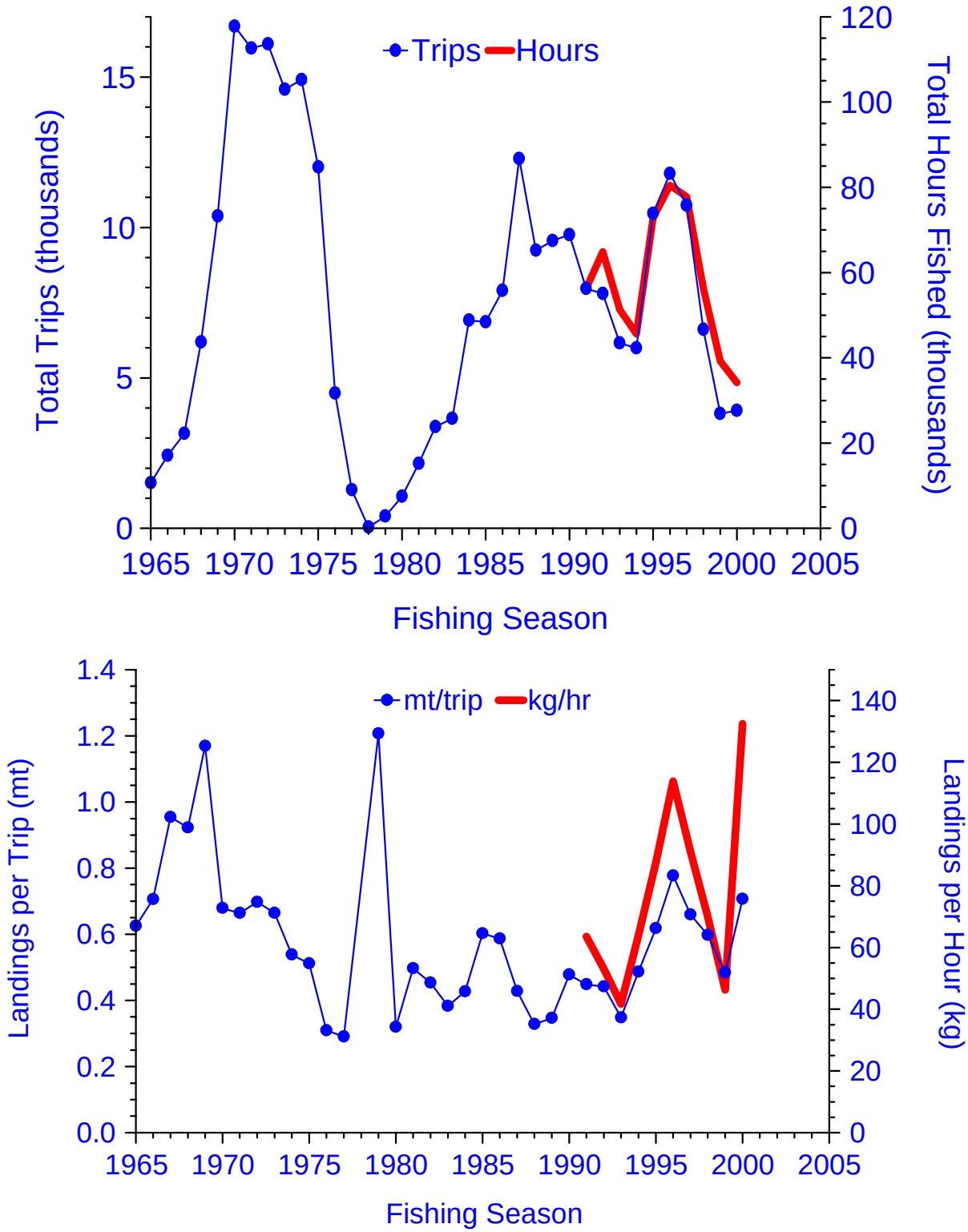


Figure 5. Nominal fishing effort (above) and catch per unit effort (below) in the Gulf of Maine northern shrimp fishery.

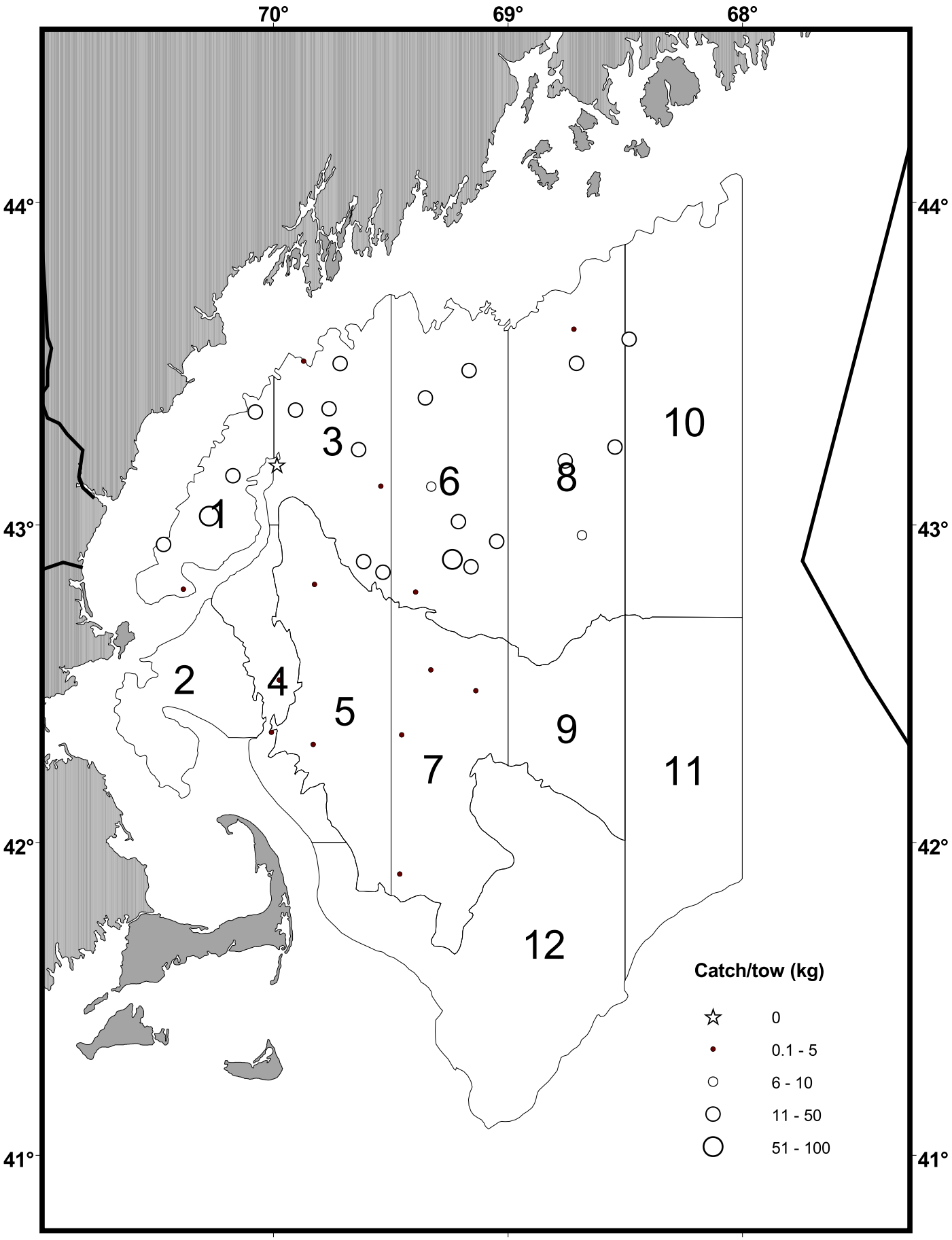


Figure 1. Northern shrimp survey strata and observed distribution of catch per tow (kg) of northern shrimp collected during the 2000 survey in the western Gulf of Maine aboard the R/V GLORIA MICHELLE, July 21-August 4, 2000.

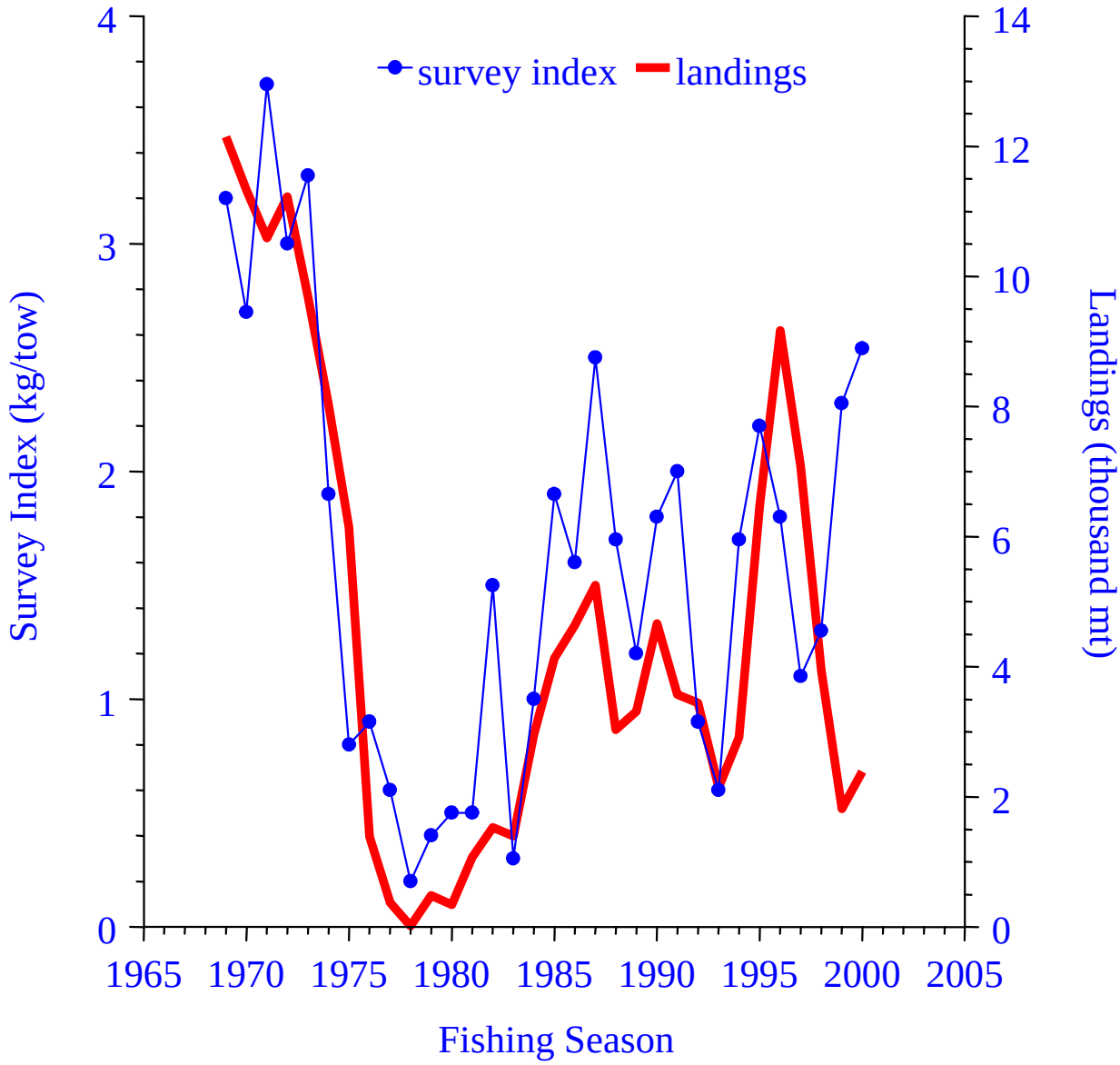


Figure 7. Fall survey index (lagged) and landings of Gulf of Maine northern shrimp.

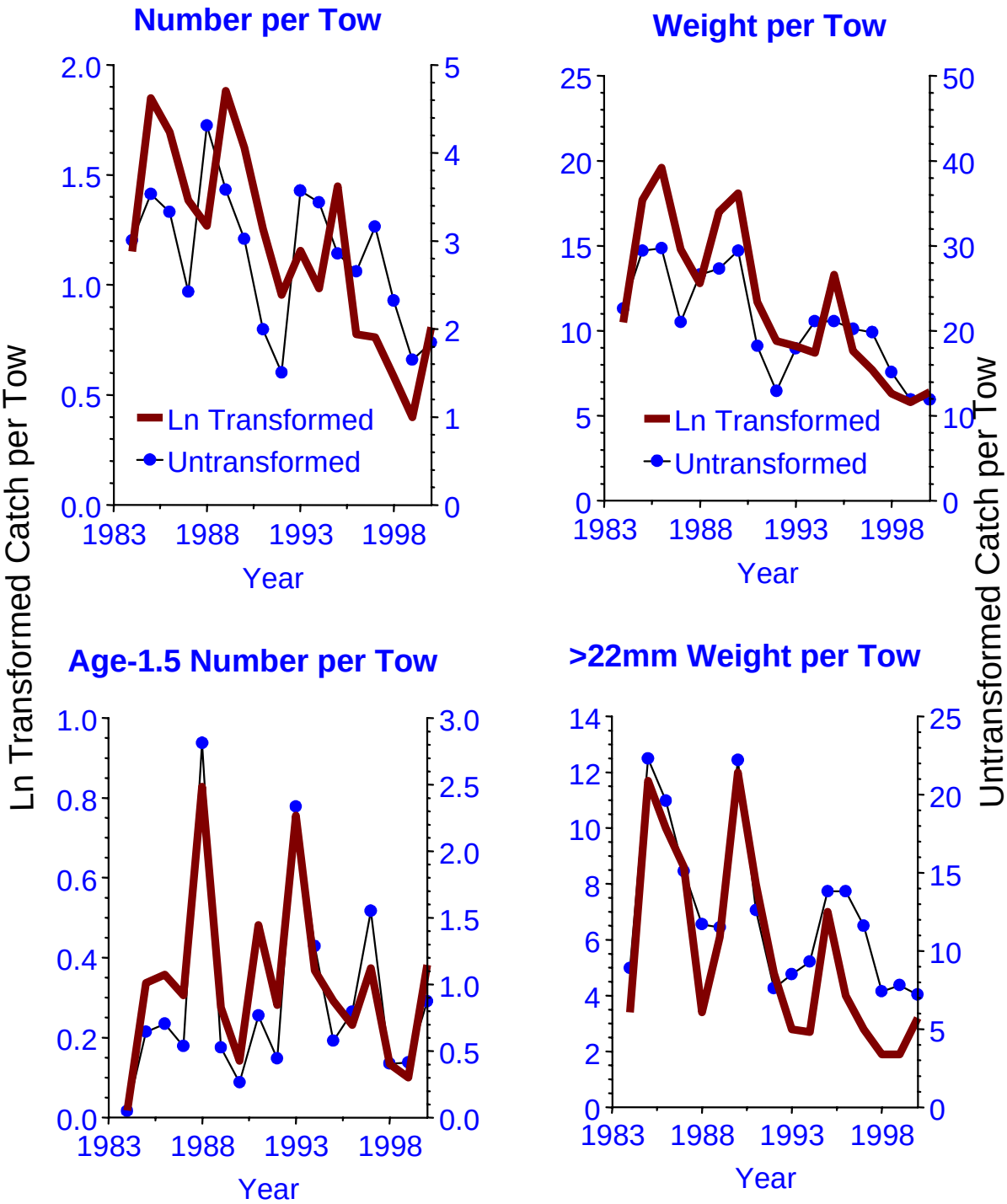


Figure 8. Gulf of Maine northern shrimp summer survey indices of abundance and biomass.

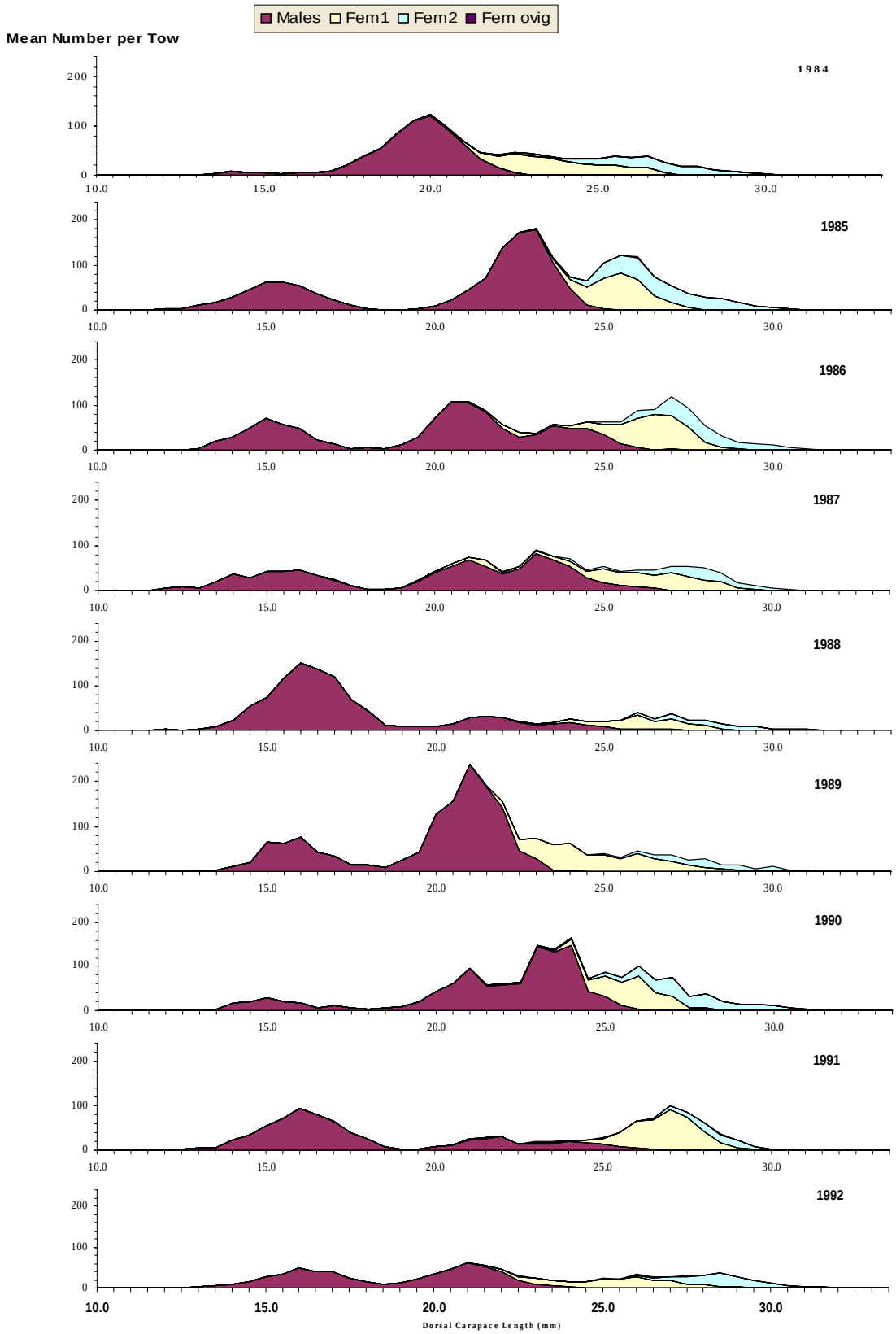


Figure 9. Gulf of Maine north shrimp summer survey mean catch per tow by length and development stage.

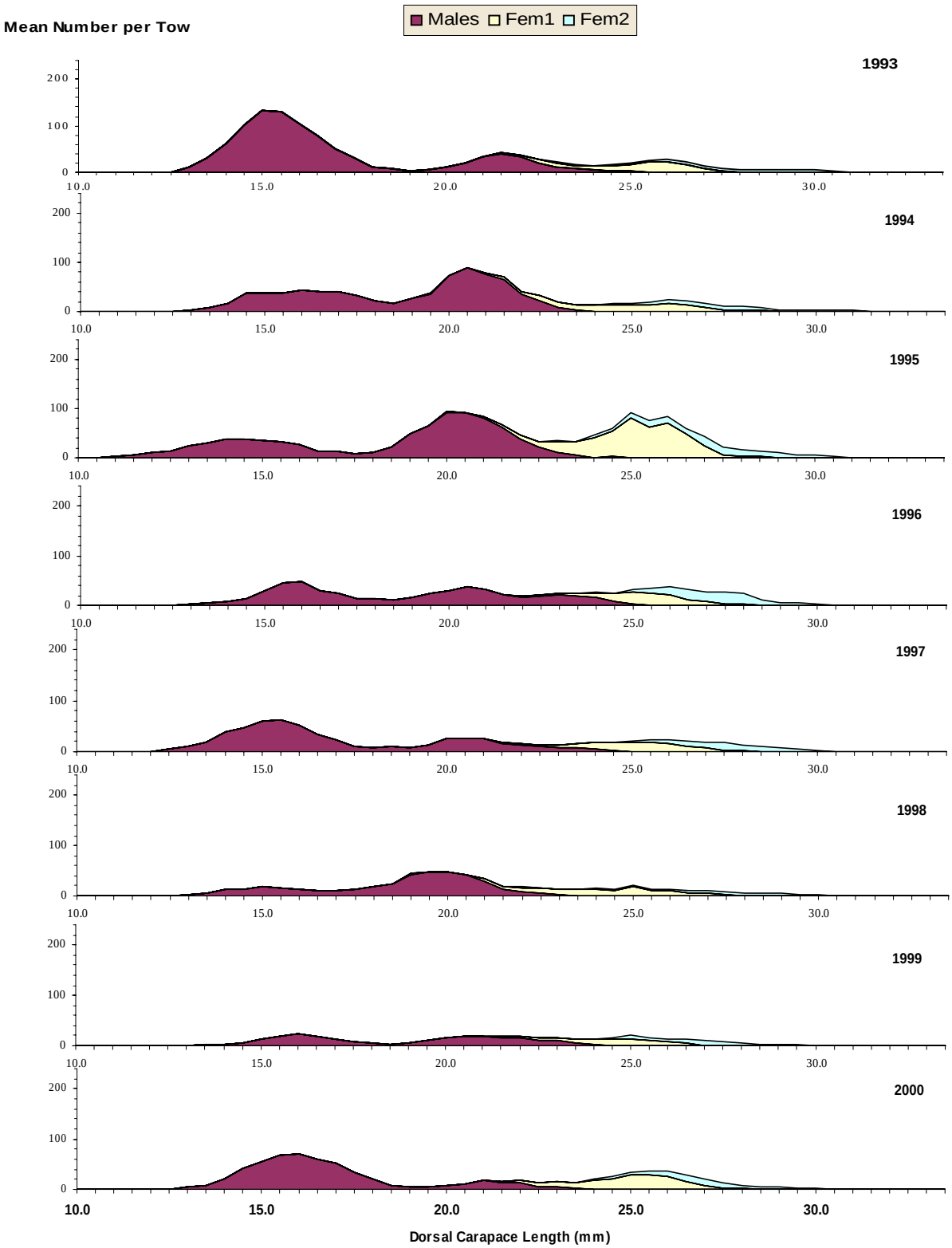
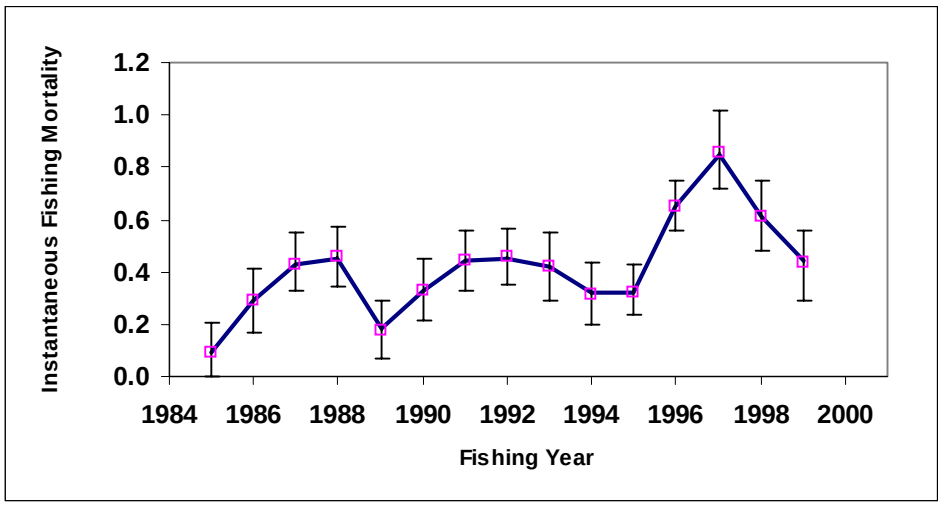
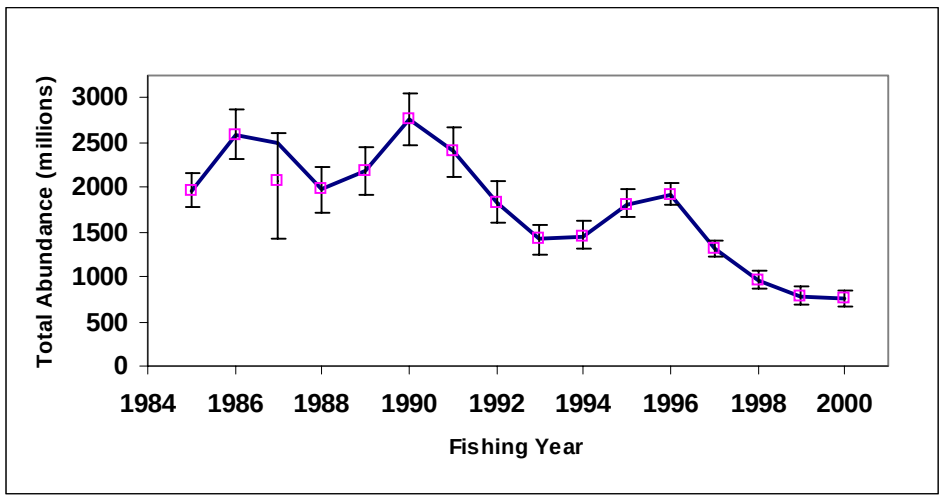


Figure 9. (continued)

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





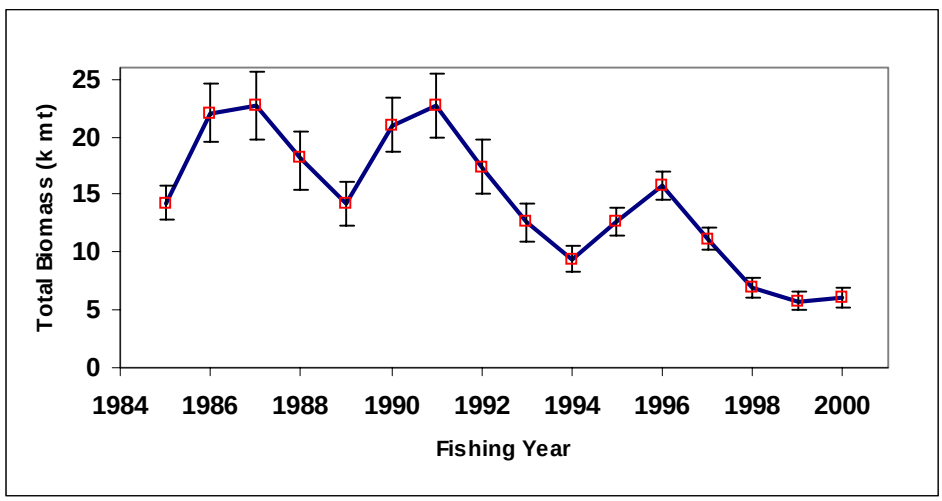


Figure 11. Catch - Survey Model (Modified DeLury) Input Data and Results

Northern Shrimp
using Summer Survey

Survey Year*	Indices of Recuits	Abundance Full Recruits	Total Catch Millions
1984	447.6000	479.1000	352.7930
1985	619.5000	925.4000	361.1710
1986	533.4000	848.7000	425.2940
1987	436.3000	693.6000	228.4340
1988	459.9000	387.9000	283.6470
1989	700.7000	817.5000	442.4290
1990	511.6000	907.7000	320.2900
1991	374.1000	611.9000	262.4340
1992	313.6000	444.4000	194.7880
1993	410.0000	320.6000	270.4060
1994	368.7000	364.4000	615.3180
1995	485.9000	653.1000	799.3680
1996	257.7000	348.6000	718.4330
1997	257.4000	267.2000	373.7840
1998	217.2000	226.7000	205.1220
1999	137.4000	174.6000	209.2790
2000	276.2000	288.1000	

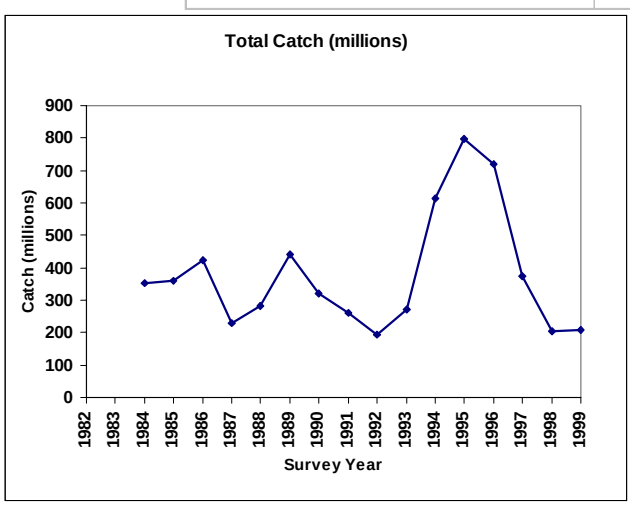
* Survey Year Data are applied to the following Fishing Year

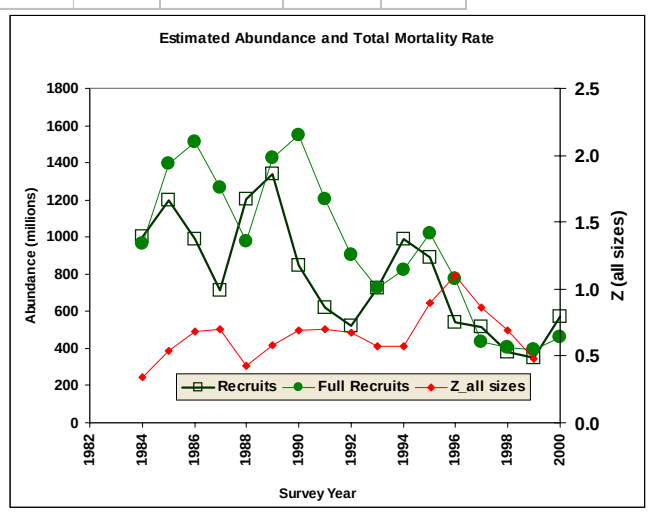
Input File Name	R100.dat
Tuning Dataset	Survey
Time of Survey (yr)	0
Time of Catch (yr)	0.5
Natural Mortality Rate	0.25
Relative Catchability: Recruits to Full Recruits s_r	0.7 - 1.0
Catchability Estimate and CV	5.39E-01 0.17
Average Partial Recruitment Rate to Fishery	0.552
Average Z_all sizes (1996-98)	0.68
Average Z_all sizes (1997-98)	0.59

Survey Year*	Stock Size millions at Recruits	Estimates time of Survey Full Recruits	Total Mortality Z_all sizes	Fishing Mortality All Sizes
1984	1004.0	963.9	0.34	0.09
1985	1196.0	1393.8	0.54	0.29
1986	988.7	1508.2	0.68	0.43
1987	710.2	1265.2	0.70	0.45
1988	1204.9	976.2	0.43	0.18
1989	1338.7	1423.4	0.58	0.33
1990	845.8	1549.8	0.69	0.44
1991	619.8	1201.7	0.70	0.45
1992	521.3	900.1	0.67	0.42
1993	723.6	727.3	0.57	0.32
1994	986.7	824.1	0.57	0.32
1995	892.9	1019.5	0.90	0.65
1996	538.7	775.8	1.10	0.85
1997	518.9	435.4	0.86	0.61
1998	380.1	404.2	0.69	0.44
1999	352.8	395.0	0.48	0.23
2000	569.185	460.998		

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 1998

* Survey Year Data are applied to the following Fishing Year





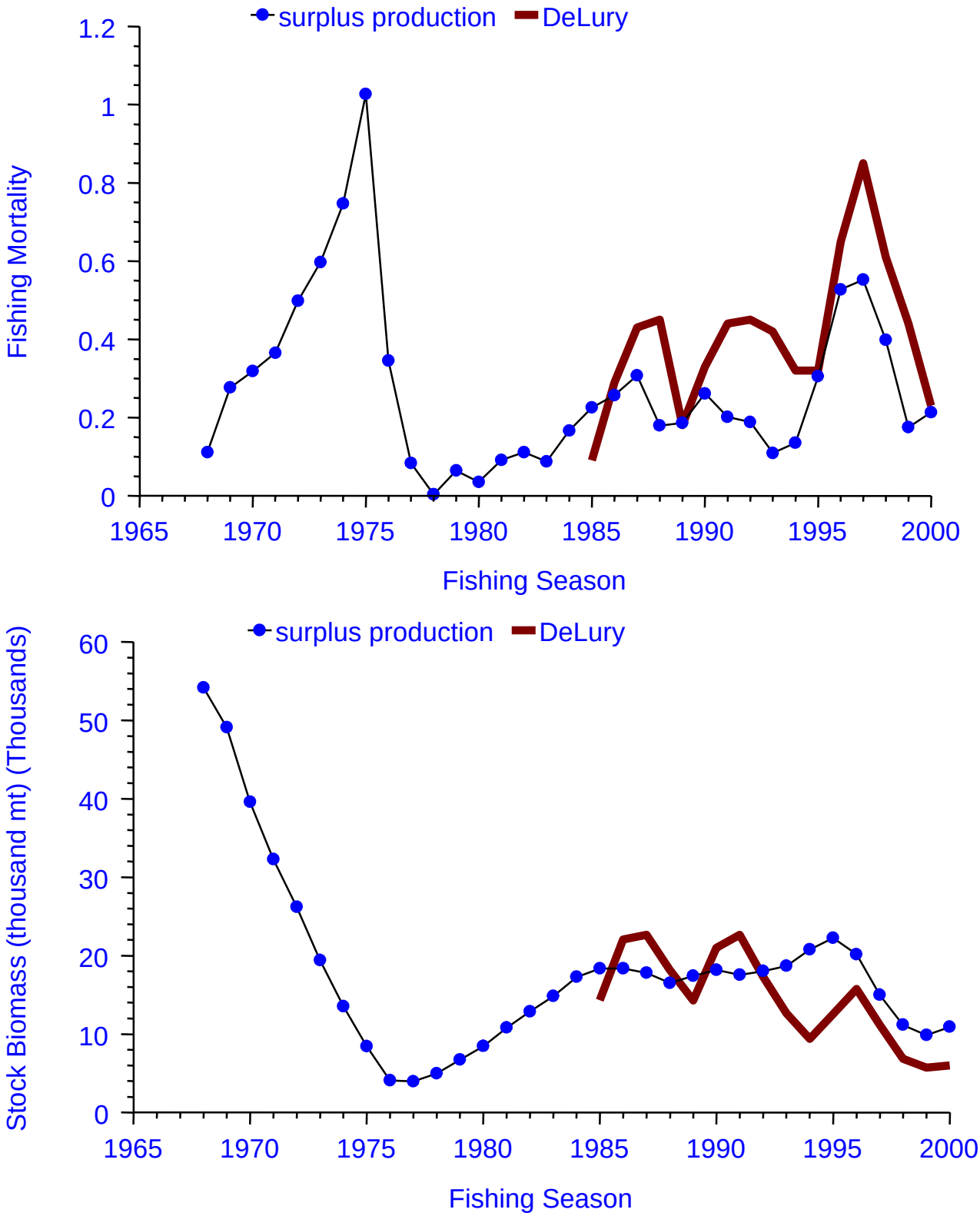


Figure 12. Estimates of fishing mortality (above) and stock biomass (below) for Gulf of Maine northern shrimp from DeLury and surplus production modeling.

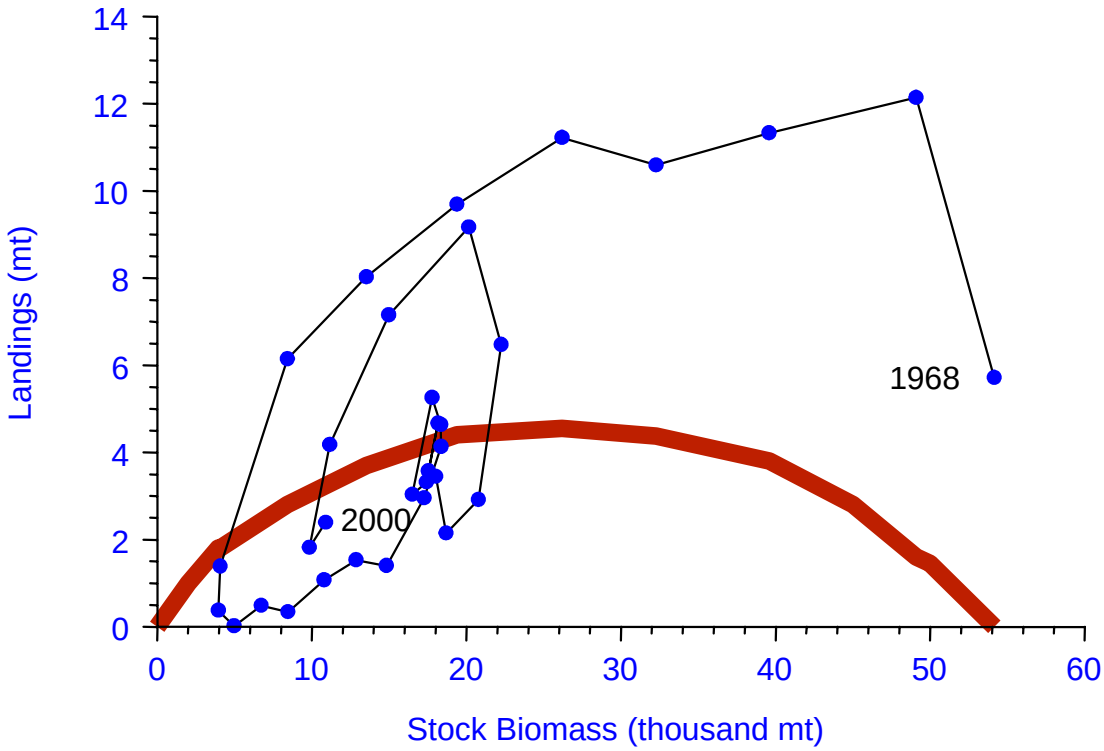


Figure 13. Biomass dynamics of Gulf of Maine northern shrimp from surplus production modeling.

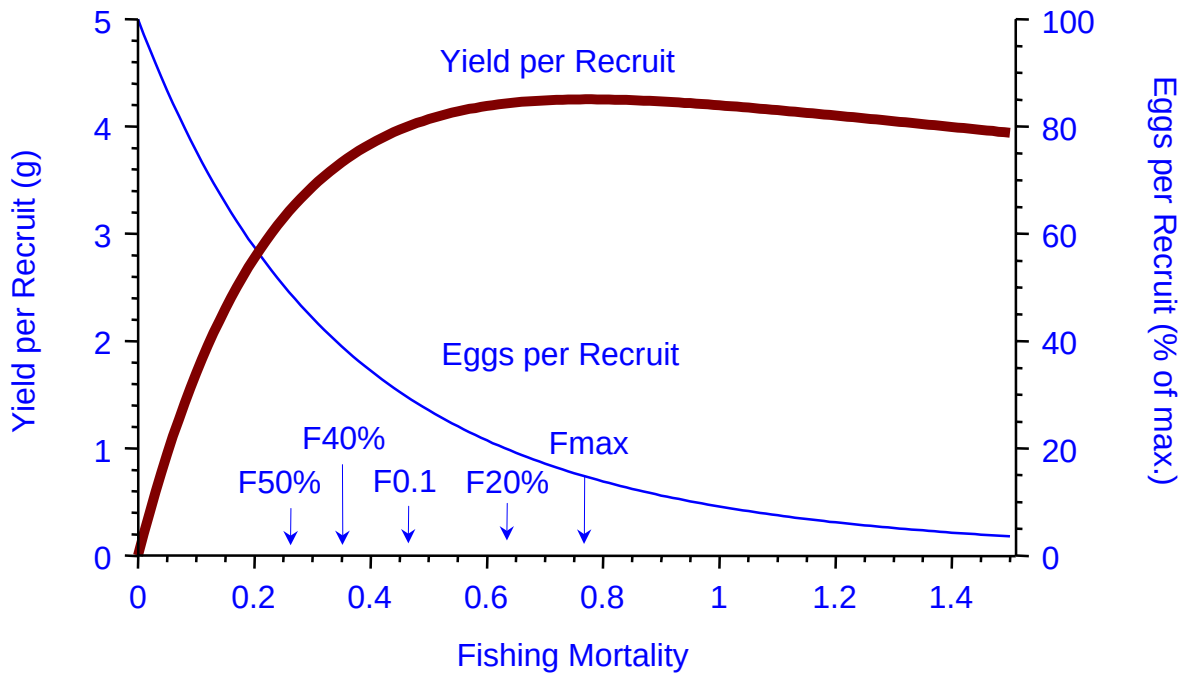


Figure 14. Yield and egg production per recruit of Gulf of Maine northern shrimp.

Figure 15. Relationship between summer survey index of Gulf of Maine northern shrimp female biomass the summer before spawning to age-1.5 abundance two years later