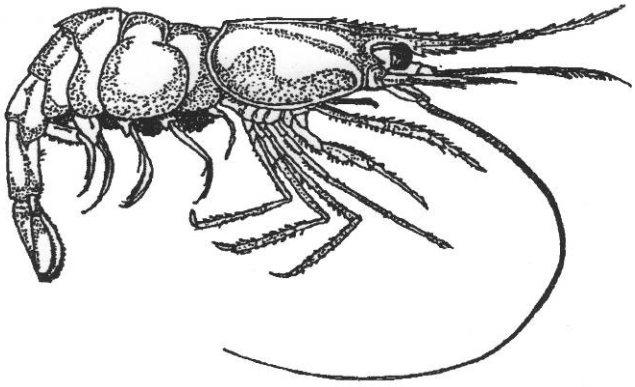
ASSESSMENT REPORT

FOR

GULF OF MAINE NORTHERN SHRIMP – 2007



Prepared

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by the

Atlantic States Marine Fisheries Commission's

Northern Shrimp Technical Committee

Margaret Hunter, Chair (Maine)

Robert Glenn, Kelly Whitmore (Massachusetts)

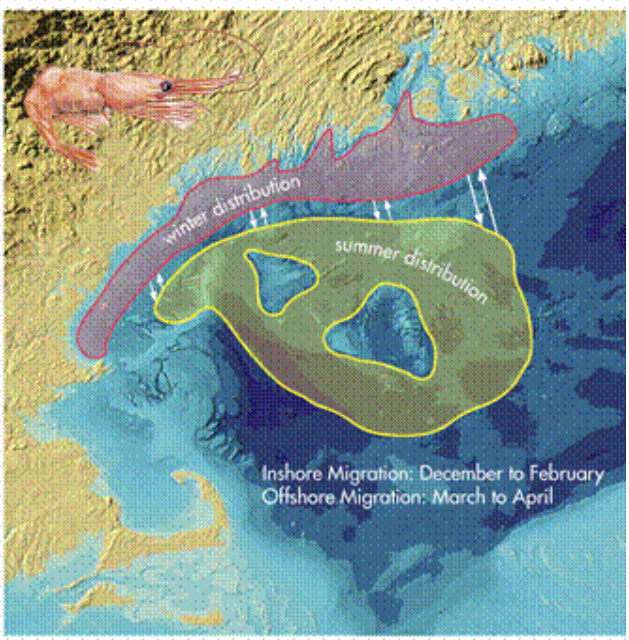
Dr. Clare McBane, (New Hampshire)

Josef Idoine, (NMFS NEFSC)

Braddock Spear (ASMFC)

INTRODUCTION

Biological Characteristics



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

Northern shrimp (*Pandalus borealis*) are hermaphroditic, maturing first as males at roughly 2½ years of age and then transforming to females at roughly 3½ years of age. In the Gulf of Maine, spawning takes place in offshore waters beginning in late July. By early fall, most adult females extrude their eggs onto the abdomen. Egg bearing females move inshore in late autumn and winter, where the eggs hatch. Juveniles remain in coastal waters for a year or more before migrating to deeper offshore waters, where they mature as males. The exact extent and location of these migrations is variable and unpredictable. The males pass through a series of transitional stages before maturing as females. Some females may survive to repeat the spawning process in succeeding years. The females are the individuals targeted in the Gulf of Maine fishery. Natural mortality seems to be most pronounced immediately following hatching, and it is believed that most shrimp do not live past age 5.

Fishery Management

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

42). Amendment 1, which entirely replaces the original FMP, establishes biological reference points for the first time in the shrimp fishery and expands the tools available to manage the fishery. Any new tools proposed to manage the shrimp fishery must be implemented through the ASMFC addendum process.

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

At its Fall 2006 meeting, the Northern Shrimp Section approved a 151-day season: December 1, 2006, through April 30, 2007, inclusive. This will be referred to as the "2007 season" throughout this document. In addition, it continued to require the use of a finfish excluder device known as the "Nordmore Grate" throughout the shrimp fishing season. The Section also maintained the requirement that made it unlawful to use mechanical "shaking" devices to cull, grade, or separate catches of shrimp. The Section also made a commitment to set the 2008 season for 151 days, provided certain triggers were not exceeded. The Section will reconsider the 2008 fishing season length if, during the 2007 fishing season:

- the number of fishing trips exceeds 7,000
- landings exceed 8,000 metric tons, or
- fishing mortality exceeds 0.20.

and with consideration of the 2007 summer shrimp survey results.

Fishery Assessment

Stock assessments conducted since the 1980's have keyed on strong year classes, (i.e. those hatched in 1982, 1987, 1992, and 2001). 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 1996, but recommended reductions in fishing effort for December, April and May for the 1997 fishery to afford some protection for small shrimp in the offshore areas. The NSTC recommended limiting the fishery to February and March for the 1998 season and a 40-day season during the months of February and March in 1999 to protect the berried females and young shrimp in light of a rapidly declining resource.

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

The Committee took a different approach in 2004 with regard to its recommendations for the fishery. Instead of recommending a specific season length, it recommended maintaining a target fishing mortality rate below F=0.22. In combination, it strongly urged the Section to craft a season that would not permit landings of more than 2,500 metric tons. This approach was well received by the Advisory Panel and Section and was repeated in 2005, when the Committee

recommended that 2006 shrimp landings should be less than 5,200 metric tons. In 2006 the Committee did not oppose another season of 140 days for 2007.

The following report presents the results of the Technical Committee's 2007 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) past commercial landings data collected by the National Marine Fisheries Service (NMFS) port agents, 3) biological sampling of the commercial landings by personnel from the participating states and the NMFS, and 4) data from vessel trip reports (VTRs) filed by shrimp fishers. In addition to previously used traditional methods of assessing the stock (i.e. landings data, commercial effort and CPUE estimates, indices of abundance, etc.), more innovative, quantitative tools, such as the Collie-Sissenwine Analysis, ASPIC surplus production, yield per recruit, and eggs per recruit models were introduced in 1997 and continue to be used to provide guidance for management of the stock.

COMMERCIAL FISHERY TRENDS

Landings

Annual landings of Gulf of Maine northern shrimp declined from an average of 11,400 metric tons (mt) during 1969-1972 to about 400 mt in 1977, culminating in a closure of the fishery in 1978 (Table 1). The fishery reopened in 1979 and landings increased steadily to over 5,000 mt by 1987. Landings ranged from 2,300-4,400 mt during 1988-1994, and then rose dramatically to 9,200 mt in 1996, the highest since 1973. Landings declined 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 1,329 mt, and dropped further in the 25-day 2002 season to 424 mt, the lowest northern shrimp landings since the fishery was closed in 1978. Landings in the 2003 38-day season were 1,211 mt, with 1,949 mt in a 40-day season in 2004 and 2,561 mt in a 70-day season in 2005. Landings in the 140-day season in 2006 were 2,088 mt. (preliminary data), and 3,374 mt (preliminary data) in the 151-day 2007 season (Table 1 and Figure 1a).

Maine landed 95% (1,973mt) of the 2006 season total while New Hampshire and Massachusetts landed 4% (90 mt) and 1% (25 mt), respectively (preliminary data). Maine landed 91% (3,074mt) of the 2007 season total while New Hampshire and Massachusetts landed 9% (290mt) and 0.3% (10mt), respectively, (preliminary data). The proportional distribution of landings among the states was similar to 2003-2005, but has shifted gradually since the 1980's when Massachusetts accounted for about 30% of the catch, (Table 1 and Figure 1a).

The relative proportion of landings by month remained generally similar to past years. The month of February 2007 (28 open days) yielded the highest proportion of the catch and the greatest catch per open day. April (30 open days) exhibited the lowest proportion of the catch and the lowest catch per open day, followed by the 31 open days in March (Table 2a and Figure 1b).

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 4 to 19% of Maine's landings in 2001 to 2006 (preliminary data), and 11% (preliminary data) in 2007 (Table 2b).

Size, Sex, and Maturity Stage Composition of Landings

Size composition data (Figures 2-4), collected from catches since the early 1980s, indicate that trends in landings have been determined primarily by recruitment of strong (dominant) year classes. Landings more than tripled with recruitment of a strong 1982 year class in 1985 – 1987 and then declined sharply in 1988. A strong 1987 year class was a major contributor to the 1990-1992 fisheries. A strong 1992 year class, supplemented by a moderate 1993 year class, partially supported large annual landings in 1995 – 1998 (Figure 4). Low landings in 1999 – 2003 were due in part to poor 1994, 1995, 1997, 1998, and 2000 year classes with only moderate 1996 and 1999 year classes. Catches in 2004 were composed primarily of egg bearing, early maturing, presumed three-year-old females from the 2001 year class and a few larger females from the 1999 year-class. In 2005, catches were composed of egg bearing females and female II's from the presumed 2001 year class and males from the 2003 year class. 2006 catches were composed of egg bearing and female II's, probably from the strong 2001 year class. Catches in

March and April had significant numbers of smaller shrimp, presumably from the 2003 (transitionals and female I's) and 2004 (juveniles and males) year classes. In the 2007 fishery, landings were mostly composed of assumed 4-year-old females from the moderate to strong 2003 year class, and possibly 6-year-olds from the 2001 year class. Males, transitionals, and female I's from the strong assumed 2004 year class were also evident, as well as a few small males from the 2005 year class (Figures 2-4).

Maine trappers produced a smaller proportion of small shrimp in the landed catch than trawlers, and generally were more apt to catch large females after egg hatch, as in previous years (Figure 2). See the table below for average counts per pound by month and gear.

2007 commercial shrimp fishery average counts per pound, from port samples

	Pandalus borealis only					All shrimp species				
	Dec.	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**
Maine trawls	52	53	51	63	73	53	53	52	64	73
Maine traps	n/a	45	45	45	n/a	n/a	46	45	46	n/a
Maine total	52	52	49	56	73	53	53	50	57	73
New Hampshire	44	52	60	65	59	44	53	61	65	60

Spatial and temporal differences in the timing of egg-hatch can be estimated by noting the relative abundance of ovigerous females to females that have borne eggs in the past but are no longer carrying them (female stage II). According to port samples, in December 2006, in Maine, 5.7% of the trawled catch was female stage II; in January, this increased to 12.5% and in February it increased to 39.9%. In March female stage II's further increased to 59.5%, but in April declined to 38.0% when the proportion of males, transitionals, and females I's in catches increased. Maine trappers caught 35.7% female stage II in January, 67.5% in February, and 91.9% in March, consistently higher than the trawl catches each month (Figure 2). Maine trap catches also contained fewer small (males and transitionals < 24 mm) *P. borealis* than trawl catches (Figure 2).

In New Hampshire trawl catch samples, the percentage of female stage II shrimp was 11.3% in December 2006, 38.4% in January, 46.0% in February, 34.4% in March and 54.7% in April (Figure 3), possibly reflecting the western Gulf of Maine leading the east in the timing of egg hatch. As the 2007 season progressed, Maine and New Hampshire showed a reduction in females carrying eggs with no eggs being carried in April. Port sample data for Massachusetts were not available this year.

Discards

Reports from port samplers indicate that there was some discarding of small shrimp in the Maine fishery in December. Because of the lack of detailed information, discarding is not incorporated into this assessment.

Black Gill Syndrome

Shrimp collected during routine port-sampling in Maine in 2003 exhibited a high incidence (greater than 70%) of Black Gill Syndrome, also called Black Gill Disease or Black Spot Syndrome. Affected shrimp displayed melanized, or blackened gills, with inflammation, necrosis, and significant loss of gill filaments. Black Gill Syndrome has also been documented in white shrimp in South Carolina (http://praise.manoa.hawaii.edu/news/eh216.html) and in the Gulf of Maine in the 1960s and 1970s (Apollonio and Dunton, 1969; Rinaldo & Yevitch, 1974). Its etiology is unknown, although fungal and ciliated protist parasites have been implicated. In samples collected in Maine during the 2004 - 2007 fisheries, the incidence of Black Gill Syndrome was much lower, and detected cases were much less severe, than in 2003.

Effort and Distribution of Effort

Since the late 1970's, effort in the fishery (measured by numbers of trips in which shrimp gear is used) has increased and then declined on three occasions. The total number of trawl trips in the fishery peaked at 12,285 during the 1987 season (Table 3a, 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 5,990 trips in the 1994 season. Effort nearly doubled between 1994 and 1996 and then declined again from the 1996 level of 11,791 to 1,010 trips in 2002, a year with only a 25-day open season. The number of trips increased during

2003-2005 as the seasons were lengthened, to 3,088 trawl trips in 2005. Trips in 2006 dropped to 1,800 (preliminary), likely due to poor market conditions, and increased in 2007 to 2,392 (preliminary, Table 3a).

The number of vessels participating in the fishery in recent years has varied from a high of 310 in 1997 to a low of 144 (preliminary) in 2006.

Year	Vessels	Year	Vessels
1997	310	2003	248
1998	260	2004	190
1999	238	2005	202
2000	285	*2006	144
2001	288	*2007	150
2002	200	*preliminary	

In 2007, there were 3 vessels from Massachusetts, 132 from Maine, and 15 from New Hampshire, for a total (preliminary) of 150. Of these, 51 of the Maine boats were trapping.

Maine trapping operations accounted for 18%, 25%, 34%, and 25% of Maine shrimp fishing trips in 2004-2007 respectively, according to VTR data (preliminary) (Table 3b).

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 2006 and 2007 are still being received and processed. Therefore, landings and effort estimates reported here for recent years should be considered extremely preliminary. The 1996 assessment report (Schick et al. 1996) provides a comparison of 1995 shrimp catch and effort data from both the NEFSC interview and logbook systems and

addresses the differences between the systems at that time. It showed a slightly larger estimate from the logbook system than from the interview system. Thus effort statistics reported through 1994 are not directly comparable to those collected after 1994. However, patterns in effort can be examined if the difference between the systems is taken into account. An additional complication of the logbook system is that one portion of the shrimp fishery may not be adequately represented by the logbook system during 1994-1999. Smaller vessels fishing exclusively in Maine coastal waters are not required to have federal groundfish permits and were not required to submit shrimp vessel trip reports until 2000. In the 1994-2000 assessments, effort from unpermitted vessels was characterized by catch per unit effort of permitted vessels.

Seasonal trends in distribution of trawl effort can be evaluated from port interview data. The relative magnitude of offshore fishing effort (deeper than 55 fathoms) has varied, reflecting seasonal movements of mature females (inshore in early winter and offshore following larval hatching), but also reflecting harvesters' choices for fishing on concentrations of shrimp. In the 2007 season in Maine, sampled trips were generally offshore in December and April, about 60% inshore during January, 100% inshore in February, and about 40% inshore in March, based on a total of 157 trawler interviews. In New Hampshire, most sampled trips were offshore, except during February, when 75% of the sampled trips were in 50 fathoms or less.

Locations of 2007 fishing trips and landings from federal VTRs are plotted by 10-minute square in Figure 6a. Locations for 2001 – 2006 are plotted in Appendix A.

Catch per Unit Effort

Catch per unit effort (CPUE) indices have been developed from NMFS interview data (1983-1994) and logbook data (1995-2006) and are measures of resource abundance and availability. (See table below and 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 trawl trip, from logbooks, averaged 1,393 pounds during 1995-2000. In 2001, the catch per trip dropped to 740 pounds, the lowest since 1988, and remained low, at 831 pounds, in 2002. In 2003, the catch per trip was 1,029 pounds, and in 2004 it was 1,821 pounds per trip. In 2005 it was 1,545; in 2006 it was 2,220 (preliminary), and in 2007 it was 2,807 pounds per trip (preliminary), the highest in the time series (Figure 5 and table below).

More precise CPUE indices (pounds landed per hour fished) have also been developed for both inshore (depth less than 55 fathoms) and offshore (depth more than 55 fathoms) areas using information collected by Maine's port sampling program, and agree well with the (less precise) catch per trip data from logbooks (see table below and Figure 5). Maine inshore CPUE for 2007 was 531 lbs/hr, offshore was 477 lbs/hr, and the season average was 507 lbs/hr, all time-series highs.

Maine CPUE in lbs/hour towed, from port sampling. Catch in lbs/trip is from NMFS weighout and logbook data for trawl catches for all states.

Year	Maine pounds per hour towing			Pounds/trip
	Inshore (<55F)	Offshore (>55F)	Combined	
1991	94	152	140	988
1992	132	93	117	974
1993	82	129	92	767
1994	139	149	141	1,073
1995	172	205	193	1,362
1996	340	203	251	1,714
1997	206	192	194	1,454
1998	158	151	154	1,317
1999	159	146	152	1,067
2000	288	337	292	1,444
2001	100	135	109	740
2002	223	91	194	831
2003	174	215	182	1,029
2004	361	310	351	1,821
2005	235	212	228	1,545
2006	572	345	499	2,220
2007	531	477	507	2,807

RESOURCE CONDITIONS

Trends in abundance have been monitored since the late 1960's from data collected in Northeast Fisheries Science Center (NEFSC) spring and autumn bottom trawl surveys and in summer surveys by the State of Maine (discontinued in 1983). A state-federal shrimp survey was initiated by the NSTC in 1984. The latter survey is conducted each summer aboard the *R/V Gloria Michelle* employing a stratified random sampling design and gear specifically designed for Gulf of Maine conditions. The NSTC has placed primary dependence on the summer survey for fishery-independent data used in stock assessments, although NEFSC autumn survey data have been valuable as well.

There has generally been good agreement (r = 0.63) between the NEFSC autumn survey index (Table 6, stratified mean catch per tow, kg) and fishery trends (Figure 7). This index was nearly at all time highs at the beginning of the time series in the late 1960's and early 1970's when the Gulf of Maine Northern shrimp stock was at or near virgin levels. In the late 1970's the index declined precipitously as the fishery collapsed; this was followed by a substantial increase in the middle 1980's to early 1990's, with peaks in 1986, 1990 and 1994. This reflects recruitment and growth of the strong 1982, 1987 and 1992 year classes and the above average 1993 year class. After declining to 1.17 kg/tow in 1996, the index rose sharply in 1998 and 1999 to 2.26 and 2.39 kg per tow respectively, both well above the time series mean of 1.71 kg/tow. This is likely due to recruitment of the 1996 year class to the survey gear. Beginning in 2000, the fall survey index declined precipitously for three consecutive years reaching a low of 0.63 kg/tow in 2002, indicating very poor 1997, 1998, and 2000 year classes. From 2002 to 2006, the index generally increased each year, reaching an unprecedented time series high of 6.64 kg/tow in 2006. The elevated fall survey indices observed since 2002 are indicative of robust 2001 and 2004 year classes and moderate 2003 and 2005 year classes.

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the state-federal summer survey from 1984-2007 are given in Table 4 and Figures 6b and 8, and length-frequencies by year are provided in Figure 9. The $\log_e$ transformed mean weight per tow averaged 15.8 kg/tow from 1984 through 1990. Beginning in 1991 this index began to decline

and averaged 10.2 kg/tow from 1991 through 1996. The index then declined further, averaging 6.1 kg/tow from 1997 through 2001, and reaching a time series low of 4.3 kg/tow in 2001. In 2002 the index increased to 9.2 kg/tow, and then declined to the second lowest value in the time series (5.5 kg/tow) in 2003. Since 2003, the index has increased markedly, reaching a new time series high in 2006 (66.0 kg/tow). This trend should be viewed with caution because the 2006 summer survey indices were based on 29 tows, compared with about 40 tows in most years (Table 4). In 2007, with 43 tows conducted, the index decreased to 10.9 kg/tow. The total mean number per tow demonstrated the same general trends over the time series (Table 4).

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 (left-most) 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 1987, 1992, 2001, and 2004 year classes, and moderately strong year classes for 1990, and 1999. The 1997 and 1998 age classes were weak, both well below the time series mean of 392 individuals per tow. In 2001 the age 1.5 recruitment index was at its lowest level since 1984, with a stratified mean of 18 individuals per tow on the transformed scale, representing recruitment failure of the 2000 year class. In 2002 the age 1.5 recruitment index increased dramatically to 1,164, which was the time series high and represents an extremely strong 2001 year class. It is interesting to note that in the 2002 summer survey, more small females (< 19 mm CL, assumed 1.5 years old) were caught than at any other time in the history of the survey (Figure 9). The index subsequently dropped to 11 individuals per tow in 2003, indicating a very poor 2002 year class, the worst in the time series. The index increased in 2004 to 286 individuals per tow, and reached a time series high in 2005 (1,753 individuals per tow). This is indicative of a moderate 2003 year class and a very strong 2004 year class. The age 1.5 recruitment index dropped in 2006 (374 individuals per tow) and again in 2007 (24 individuals per tow), indicating a moderate 2005 year class and very weak 2006 year class.

The record 2001 year class appeared in a greatly diminished state in the 2003 survey, yet stabilized in the 2004 and 2005 surveys. The re-appearance of the 2001 year class as indicated by the increased abundance of presumed 3.5 year old shrimp in the 2004 summer survey is

evidence that the distribution of shrimp in the summer of 2003 made them, to some unknown extent, unavailable to the summer survey that year. This also supports anecdotal reports that shrimp stayed "inshore" in 2003, in areas not visited by the survey. It is not so clear why the 2001 year class appeared to increase again in abundance between 2004 and 2005 (Figure 9, rightmost mode in 2004 and 2005 surveys). The virtually absent 2002 year class first observed in the 2003 survey remained very weak in the 2004 and 2005 surveys, however.

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 and 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 until 2004. The 2001 index of 1.5 kg/tow represented a time series low, and is indicative of poor 1997 and 1998 year classes. In 2002 the index increased slightly to 2.9 kg/tow, reflecting recruitment of the moderate 1999 year class to the index. The index subsequently dropped to the second lowest value in the time series (1.7 kg/tow) in 2003. From 2003 to 2006, the fully recruited index increased dramatically, reaching a time series high in 2006 (29.9 kg/tow). This increase may have been related to the continued dominance of the record 2001 year class, some of which may have survived into the summer of 2006, and to an unexplained increase in the number of female stage 1 shrimp (Figure 9), probably the 2003 year class. In 2007 the index declined to 3.4 kg/tow with the passing of the 2001 year class and the diminishing of the 2003 year class. The moderate 2007 index was unlike many other years, in that individuals >22 mm included a relatively even mix of males, female stage I, and female stage II shrimp (Figure 9).

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 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 0.7 billion individuals from 1985 through 1990, declining (average 0.5 billion) through 1991 to 1994. Recruit abundance rose to 0.9 billion before the 1995 and 1996 fishing seasons, then declined steadily to less than 0.3 billion before the 2002 fishing season. Estimates of 2.5 and 2.2 billion (2005 and 2006 respectively) are the highest seen (from 1984 through 2008). Current abundance is estimated to be 0.4 billion. Fully-recruited abundance averaged 1.0 billion individuals and peaked at 1.1 billion before the 1991 season. Since that point, fully-recruited abundance declined steadily to 0.3 billion before 2001, and then increased to 3.3 (2.5 in 2007) billion in the current year. Total stock biomass estimates averaged about 13,000 mt, with a peak at 15,400 mt before the 1991 season, and a decrease to a time series low of 4,300 mt in 2001. Total stock biomass has increased over recent years to its current value of 32,000 mt, down slightly from the series high of 34,100 mt in 2007 (Table 5, Figures 10, 11).

The recent two years of high abundance and low F are due, in part, to the same years of observed very high survey catches and very low reported landings that have leveraged those estimates to account for those observations. Since 2002, both fall and summer survey indices have been increasing, and the reported landings have followed a similar pattern, offset by a year.

Recent assessments have estimated fishing mortality rates (F) based on “harvest rate” derived F’s.

$$U = \frac{F * (1 - e^{-Z})}{Z}$$

For the most recent peer reviewed assessment (SARC 45), a revision was made to the CSA that allows the use of an "exact" solution, using the catch equation.

$$\frac{C_t}{q} = \frac{F_t\left(1-e^{-zt}\right)n_t}{Z_t}$$

These two methods provide the same estimates in terms of F and μ (exploitation).

Annual estimates of fishing mortality (F) averaged 0.25 (19% exploitation) for the 1985 to 1994 fishing seasons, peaked at 1.07 (57% exploitation) in the 1997 season and decreased to 0.31 (23% exploitation) in the 2001 season (Table 5; Figures 10, 11). In 2002 F dropped to 0.09 (7% exploitation), due in part to a short season and poor stock conditions. Continued poor stock conditions (in terms of exploitable shrimp) along with an exceptional recruitment pulse resulted in F rising to 0.23 (18% exploitation) in 2004. The 2007 estimate of F is 0.09 (8% exploitation). Recent patterns in F reflect the pattern in nominal fishing effort (Tables 3 and 5, Figures 5 and 10).

Precision of CSA estimates was assessed by "bootstrap" analysis, in which survey measurement errors were randomly shuffled 2000 times to provide simulated replications of the model. Bootstrap results suggest that estimates of abundance, biomass and mortality were relatively precise (Figure 10).

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

An alternative method of estimating stock size and F was used to corroborate results from CSA analysis. A surplus production model (ASPIC) was fit to seasonal catch and survey biomass indices from 1968 to 2007 (summarized in Table 6). F in 2007 (F = 0.12) is below the fishing mortality target/threshold (F = 0.22) established in Amendment 1 to the northern shrimp Fishery Management Plan. The 2007 starting biomass (27,360 mt) was at its highest level since 1971,

and is above the average observed in the time period from 1985 through 1994 when the Gulf of Maine Northern shrimp biomass was stable (16,113 mt).

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

Estimates of F and Biomass from the surplus production model generally confirmed the pattern of estimates from the CSA model between 1985 and 2005 (Figures 12 and 13). However, the 2006 and 2007 estimates of biomass from the CSA diverged greatly from the surplus production estimates for the first time. This divergence casts some uncertainty on the accuracy of the magnitude of the biomass estimates from the CSA model in these years. The terminal year values of fishing mortality and biomass in both models are typically poorly estimated. Furthermore, in this particular instance, the CSA biomass estimates were likely sensitive to the unprecedented high summer survey abundance index values observed in 2005 and 2006. As such, managers should view the magnitude of the 2006-2008 CSA biomass estimates with caution. This is further supported by a re-convergence of the biomass projections from CSA and surplus production models for 2008 and is likely the result of a 2007 survey index that is likely more reflective of resource conditions. Without question the 2007 biomass of northern shrimp was high, but possibly not quite as high as projected by the CSA model.

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 a target F well below 0.6. A sustainable target F may be the average F from 1985 through 1994, which was 0.25 (which allows 50% egg production per recruit) (Table 7, Figure 13).

SUMMARY

Landings in the Gulf of Maine northern shrimp fishery declined since the mid 1990's, from a high for the decade of 9,166 mt in 1996 to a low of 424 mt in 2002, the result of low abundances of shrimp and reductions in fishing effort. Since then, landings have increased to 3,374 mt in the 151-day 2007 season (preliminary). The 2007 season was characterized by exceptionally high catch rates and poor price. The number of fishing vessels and trawl trips have dropped from about 310 and 10,734 respectively in 1997 to 150 and 2,392 in 2007 (preliminary), although vessel reporting, particularly from the Maine small boat fleet, has probably improved. Fishing mortality rates (F), as calculated by CSA, have declined from 1.06 in 1997 to 0.09 in 2007 (preliminary). F was above the 1985-1994 average (the target or threshold F in the FMP) every year from 1995 through 2001.

Current landings, vessels, trips, and fishing locations are calculated from vessel trip reports (VTRs). Note that 2006 landings were incomplete when calculated from VTRs in October of 2006 (Tables 1-2, 2006 assessment), and went up by 11% when recalculated in September 2007 (Tables 1-2 here). Thus it must be assumed that 2007 vessel trip reports are also incomplete at this time, particularly for Maine harvesters who do not hold federal permits. However, it can be concluded that the 2007 fishery was conducted both inshore and offshore, with limited participation, poor prices and high fuel costs, outstanding catches per trip and per hour, and a catch comprised mostly of assumed 4-year-old female shrimp from the 2003 year class.

Exploitable biomass as estimated from CSA declined from 13,700 mt at the beginning of the 1996 season to a time series low of 4,300 before 2001. Since then the biomass estimate has risen to 12,100 mt before 2005, as a result of the appearance of the strong 2001 year class, and to 32,000 mt for the 2008 season, driven by high summer survey indices for 2005 and 2006. The technical committee notes that there is a high degree of uncertainty around terminal year estimates, however. Exceptionally high survey indices from the 2006 summer survey, which had fewer tows than usual, also add a source of uncertainty.

Size composition data from both the fishery and summer surveys indicate that good landings have followed the recruitment of strong (dominant) year classes. Poor landings from 1998 to 2004, as well as low biomass estimates, can be attributed in part to the below-average recruitment of the 1994, 1995, 1997, 1998, 2000, and 2002 year classes. In 2008, the 2003 year class (assumed 5-year-old females), which first appeared as a moderate year class in 2004, and the assumed 4-year-old females from the strong 2004 year class, will contribute most to landings, and the moderate to weak 2005 year class and very weak 2006 year class will be males and juveniles.

RECOMMENDATIONS

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

The committee recommends that the Section continue its recent efforts to maintain fishing mortality at conservative rates, that is, below the FMP target/threshold value of 0.22. The moderate 2003 and strong 2004 year classes present welcome opportunities to continue rebuilding the stock. A moderate to weak 2005 year class and the apparent recruitment failure of the 2006 year class are concerns.

At its Fall 2006 meeting, the Northern Shrimp Section made a commitment to set the 2008 season for December 1 through April 30 (152 days), provided certain triggers were not exceeded, and considering the 2007 summer survey results. The Section would reconsider the 2008 fishing season length if, during the 2007 fishing season:

- the number of fishing trips exceeds 7,000
- landings exceed 8,000 metric tons, or
- fishing mortality exceeds 0.20

Although landings and trips data for the 2007 season are incomplete at this time, it is likely that none of these triggers were exceeded during the 2007, 151-day season.

Since, according to all available data, stock conditions are good, the committee does not oppose a 152-day season for 2008. However, making a commitment now, to fish another 151 days in the 2009 season, is not recommended at this time.

Short-term commercial prospects are good; the abundance of shrimp greater than 22 mm is currently near median levels for the 1984-2007 survey period. If these shrimp follow traditional patterns of migrating and aggregating behavior, a 2008 fishery can anticipate good catches at current levels of fishing effort. Because of the relative strength of the 2004 year class compared with 2003, we expect catches in 2008 to be comprised of mostly 4-year-old female shrimp, with counts per pound similar to those in the 2007 fishery. However, if the female shrimp fail to separate themselves from the smaller males, and if the fishery is conducted when the year classes are mixed, a "mixy" product will result, and an opportunity to husband the 2004 and 2005 year classes will be lost.

The committee notes that the unusually high 2006 survey indices conflict with the previous two years' and the following year's lower indices (Table 4 and Figure 9). That survey was conducted with fewer tows than usual (Table 4), and it is possible that the 2006 survey results are biased. These inconsistencies contribute a high level of uncertainty to this year's assessment.

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

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Table 1. Commercial landings (mt) of northern shrimp in the western Gulf of Maine, 1958-2007.

Year	Maine		Massachusetts		New Hampshire		Total		Price
	Annual	Season	Annual	Season	Annual	Season	Annual	Season	$/Lb
1958	2.3		0.0		0.0		2.3		0.32
1959	5.4		2.3		0.0		7.7		0.29
1960	40.4		0.5		0.0		40.9		0.23
1961	30.4		0.5		0.0		30.9		0.20
1962	159.7		16.3		0.0		176.0		0.15
1963	244.0		10.4		0.0		254.4		0.12
1964	419.4		3.1		0.0		422.5		0.12
1965	947.0		8.0		0.0		955.0		0.12
1966	1,737.8		10.5		18.1		1,766.4		0.14
1967	3,141.1		10.0		20.0		3,171.1		0.12
1968	6,515.0		51.9		43.1		6,610.0		0.11
1969	10,992.9		1,772.9		58.1		12,823.9		0.12
1970	7,712.8		2,902.1		54.4		10,669.3		0.20
1971	8,354.7		2,723.8		50.8		11,129.3		0.19
1972	7,515.6		3,504.5		74.8		11,094.9		0.19
1973	5,476.7		3,868.2		59.9		9,404.8		0.27
1974	4,430.7		3,477.3		36.7		7,944.7		0.32
1975	3,177.0		2,080.2		29.5		5,286.7		0.26
1976	617.2		397.8		7.3		1,022.3		0.34
1977	148.0		236.9		2.3		387.2		0.55
1978	0.0		0.0		0.0		0.0		0.24
1979	32.9		451.3		2.3		486.5		0.33
1980	71.4		260.3		7.4		339.1		0.65
1981	528.6		538.1		4.5		1,071.2		0.64
1982	883.2	853.3	658.5	655.3	32.8	21.6	1,574.5	1,530.2	0.60
1983	1,022.0	892.5	508.0	458.4	36.5	46.2	1,566.5	1,397.1	0.67
1984	2,564.7	2,394.9	565.3	525.1	96.8	30.7	3,226.8	2,950.7	0.49
1985	2,956.9	2,946.4	1,030.6	968.0	207.4	216.5	4,194.9	4,130.9	0.44
1986	3,407.3	3,268.2	1,085.6	1,136.3	191.1	230.5	4,684.0	4,635.0	0.63
1987	3,534.2	3,673.2	1,338.7	1,422.2	152.5	157.8	5,025.4	5,253.2	1.10
1988	2,272.4	2,257.2	631.5	619.6	173.1	154.5	3,077.0	3,031.3	1.10
1989	2,542.6	2,384.0	749.6	699.9	314.3	231.5	3,606.5	3,315.4	0.98
1990	2,961.5	3,236.1	993.2	974.3	447.3	451.2	4,402.0	4,661.6	0.72
1991	2,431.1	2,488.1	727.6	801.1	208.2	282.2	3,366.9	3,571.4	0.93
1992	2,973.9	3,054.1	291.6	289.1	100.1	100.0	3,365.6	3,443.6	0.99
1993	1,562.8	1,492.2	300.3	292.8	441.1	357.4	2,304.7	2,142.9	1.03
1994	2,815.5	2,239.3	374.4	247.5	520.9	428.0	3,710.8	2,914.8	0.79
1995		5,022.7		678.8		764.9		6,466.4	0.88
1996		7,737.0		658.0		771.0		9,166.1	0.72
1997		6,050.0		362.8		666.3		7,079.1	0.82
1998		3,482.0		247.2		445.2		4,174.4	0.94
1999		1,523.4		75.7		217.0		1,816.1	0.93
2000		2,067.3		109.9		212.3		2,389.5	0.79
2001		1,073.4		49.2		206.4		1,329.1	0.86
**2002		364.8		7.7		51.2		423.7	1.07
**2003		1,081.20		23.1		106.7		1,211.0	0.87
**2004		1,756.0		17.5		175.2		1,948.7	0.45
**2005		2,222.9		48.5		289.9		2,561.3	0.56
**2006		1,973.1		24.8		90.2		2,088.1	0.37
**2007		3,073.8		10.3		290.2		3,374.3	

**Includes removals by experimental studies

2006 and 2007 are preliminary.

Table 2a. Distribution of landings (metric tons) in the Gulf of Maine northern shrimp fishery by state and month, 1987 - 2007.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1987 Season, 182 days, Dec 1 - May 31								
Maine	485.9	906.2	1,192.7	672.9	287.6	127.9	7.0	3,680.2
Mass.	103.5	260.0	384.9	310.2	180.8	182.8	5.7	1,427.9
N.H.	18.4	53.6	62.8	15.7	7.3	0.0	0.1	157.9
Total	607.8	1,219.8	1,640.4	998.8	475.7	310.7	12.8	5,266.0
1988 Season, 183 days, Dec 1 - May 31								
Maine	339.7	793.9	788.1	243.6	24.6	67.3	1.2	2,258.4
Mass.	14.4	225.8	255.0	104.9	8.6	10.9	0.0	619.6
N.H.	13.0	72.6	53.7	14.9	0.3	0.0	3.1	157.6
Total	367.1	1,092.3	1,096.8	363.4	33.5	78.2	4.3	3,035.6
1989 Season, 182 days, Dec 1 - May 31								
Maine	353.6	770.5	700.6	246.4	218.7	94.2		2,384.0
Mass.	26.2	197.5	154.9	104.8	160.9	55.6		699.9
N.H.	28.5	106.9	77.0	15.4	3.7	0.0		231.5
Total	408.3	1,074.9	932.5	366.6	383.3	149.8		3,315.4
1990 Season, 182 days, Dec 1 - May 31								
Maine	512.4	778.2	509.7	638.5	514.0	282.8	0.1	3,235.7
Mass.	75.6	344.4	184.8	100.2	158.9	110.0	4.3	978.2
N.H.	111.3	191.7	116.1	30.7	1.4			451.2
Total	699.3	1,314.3	810.6	769.4	674.3	392.8	4.4	4,665.1
1991 Season, 182 days, Dec 1 - May 31								
Maine	238.2	509.1	884.0	454.9	251.7	148.2	2.0	2,488.1
Mass.	90.5	174.7	175.9	131.2	93.3	133.8	1.6	801.0
N.H.	107.3	104.4	33.8	27.8	7.8	1.0		282.1
Total	436.0	788.2	1,093.7	613.9	352.8	283.0	3.6	3,571.2
1992 Season, 153 days, Dec 15 - May 15								
Maine	181.1	880.9	1,278.9	462.5	163.6	87.2		3,054.2
Mass.	17.1	148.2	73.3	47.5	2.9		0.1	289.1
N.H.	33.4	47.0	11.9	6.8	1.0			100.1
Total	231.6	1,076.1	1,364.1	516.8	167.5	87.2	0.4	3,443.7
1993 Season, 138 days, Dec 14 - April 30								
Maine	100.9	369.0	597.0	297.5	127.8			1,492.2
Mass.	19.6	82.0	81.9	62.3	42.0	5.0		292.8
N.H.	33.5	85.4	101.7	77.0	59.8			357.4
Total	154.0	536.4	780.6	436.8	229.6	5.0	0.4	2,142.8
1994 Season, 122 days, Dec 15 - Apr 15								
Maine	171.5	647.7	971.9	399.5	48.7			2,239.3
Mass.	27.1	68.0	100.8	38.8	12.8			247.5
N.H.	117.2	124.3	128.7	49.6	8.2			428.0
Total	315.8	840.0	1,201.4	487.9	69.7			2,914.8

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
1995 Season, 128 days, Dec 1 - Apr 30, 1 day per week off								
Maine	747.6	1,397.7	1,338.2	912.0	627.2			5,022.7
Mass.	210.7	154.0	104.1	111.0	99.0			678.8
N.H.	160.6	186.8	118.3	158.5	140.7			764.9
Total	1,118.9	1,738.5	1,560.6	1,181.5	866.9			6,466.4
1996 Season, 152 days, Dec 1- May 31, 1 day per week off								
Maine	1,124.1	1,678.3	3,004.6	785.2	350.4	794.5		7,737.1
Mass.	167.9	106.7	188.7	67.8	66.5	60.3		657.9
N.H.	189.8	169.5	234.0	81.9	78.8	17.1		771.1
Total	1,481.8	1,954.5	3,427.3	934.9	495.7	871.9		9,166.1
1997 Season, 156 days, Dec 1- May 27, two 5-day and four 4-day blocks off								
Maine	1,178.5	1,114.9	1,713.1	758.4	754.8	530.3		6,050.0
Mass.	90.2	110.4	111.4	49.0	1.2	0.5		362.7
N.H.	185.6	104.1	140.1	108.6	85.8	42.2		666.4
Total	1,454.3	1,329.4	1,964.6	916.0	841.8	573.0		7,079.1
1998 Season, 105 days, Dec 8-May 22, weekends off except Mar 14-15, Dec 25-31 and Mar 16-31 off.								
Maine	511.1	926.8	1,211.1	401.7	228.7	202.6		3,482.0
Mass.	49.1	78.0	90.5	14.3	15.3	0.0		247.2
N.H.	89.4	106.9	143.5	54.3	49.0	2.1		445.2
Total	649.6	1,111.7	1,445.1	470.3	293.0	204.7		4,174.4
1999 Season, 90 days, Dec 15 - May 25, weekends, Dec 24 - Jan 3, Jan 27-31, Feb 24-28, Mar 16-31, and Apr 29 - May 2 off.								
Maine	79.9	192.7	590.8	240.6	204.5	214.9		1,523.4
Mass.	25.0	23.8	16.0	2.5	8.4			75.7
N.H.	46.5	63.2	52.2	10.0	36.5	8.6		217.0
Total	151.4	279.7	659.0	253.1	249.4	223.5		1,816.1
2000 Season, 51 days, Jan 17 - Mar 15, Sundays off								
Maine		607.4	1,271.4	188.5				2,067.3
Mass.		17.4	78.7	13.8				109.9
N.H.		39.6	131.1	41.6				212.3
Total		664.4	1,481.2	243.9				2,389.5
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May								
Maine		576.0	433.5	37.1	26.5	0.3		1,073.4
Mass.		38.5	8.9	1.9	0.0	0.0		49.2
N.H.		127.9	37.4	12.1	29.0	0.0		206.4
Total		742.4	479.8	51.1	55.5	0.3		1,329.1
2002 Season, 25 days, Feb 15 - Mar 11								
Maine			285.5	76.7			2.5	364.8
Mass.			5.3	2.3			0.01	7.7
N.H.			38.0	13.3				51.2
Total			328.8	92.4			2.5	423.7

Table 2a continued.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		477.5	602.4	1.2			0.02	1,081.2
Mass.		10.5	12.6					23.1
N.H.		28.2	78.5					106.7
Total		516.2	693.5				0.02	1,211.0
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	1.8	522.3	846.5	378.0	4.7	2.7	0.03	1,756.0
Mass.		5.2	10.1	2.1				17.5
N.H.		27.3	87.4	60.5				175.2
Total	1.8	554.8	944.0	440.7	4.7	2.7	0.03	1,948.7
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	75.0	377.9	876.9	893.1				2,222.9
Mass.	5.9	8.1	25.1	9.4				48.5
N.H.	17.3	53.5	175.4	43.7				289.9
Total	98.2	439.5	1,077.4	946.2				2,561.3
***2006** Season, 140 days, Dec 12 - Apr 30								
Maine	133.0	588.9	817.8	322.7	110.7			1,973.1
Mass.	5.3	6.7	6.4	6.3	0.0			24.8
N.H.	3.4	27.9	8.7	43.8	6.5			90.2
Total	141.7	623.5	832.9	372.8	117.2			2,088.06
***2007** Season, 151 days, Dec 1 - Apr 30								
Maine	532.7	959.6	1,130.2	339.6	111.3	0.4		3,073.8
Mass.	2.2	0.4	4.4	3.4				10.3
N.H.	44.8	141.5	78.9	12.9	12.1			290.2
Total	579.7	1,101.5	1,213.4	355.9	123.4	0.4		3,374.3

* Preliminary data

Table 2b. Distribution of landings (metric tons) in the Maine northern shrimp fishery by gear type and month, 2001 - 2007.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	% of season total
2001 Season, 83 days, Jan 9 - Apr 30, Mar 18 - Apr 16 off, experimental offshore fishery in May									
Trawl		532.8	360.6	31.4	26.4	0.3		951.5	89%
Trap		43.2	72.9	5.7	0.1	0		121.9	11%
Total		576.0	433.5	37.1	26.5	0.3		1,073.4	
2002 Season, 25 days, Feb 15 - Mar 11									
Trawl			245.3	70.1			2.5	318.0	87%
Trap			40.2	6.6			0	46.8	13%
Total			285.5	76.7			2.5	364.8	
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off									
Trawl		411.3	465.6	1.2			0.02	878.1	81%
Trap		66.2	136.9	0			0	203.1	19%
Total		477.5	602.4	1.2			0.02	1,081.2	
2004 Season, 40 days, Jan 19 - Mar 12, Saturdays and Sundays off									
Trawl	1.8	510.5	807.2	361.6	4.7	2.7	0.03	1,688.4	96%
Trap		11.8	39.3	16.4	0	0	0	67.6	4%
Total	1.8	522.3	846.5	378.0	4.7	2.7	0.03	1,756.0	
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off									
Trawl	75.0	369.4	748.3	633.5				1,826.2	82%
Trap	0	8.6	128.6	259.6				396.7	18%
Total	75.0	377.9	876.9	893.1				2,222.9	
***2006** Season, 140 days, Dec 12 - Apr 30									
Trawl	132.8	571.8	654.4	228.8	110.1			1,697.9	86%
Trap	0.1	17.1	163.4	93.9	0.6			275.1	14%
Total	133.0	588.9	817.8	322.7	110.7			1,973.1	
***2007** Season, 151 days, Dec 1 - Apr 30									
Trawl	528.9	928.5	911.7	264.7	110.8	0.4		2,745.1	89%
Trap	3.7	31.1	218.5	74.9	0.5	0.0		328.7	11%
Total	532.7	959.6	1130.2	339.6	111.3	0.4		3,073.8	

* Preliminary data

Table 3a. Distribution of fishing effort (number of trawl trips) in the Gulf of Maine northern shrimp fishery by state and month, 1987 – 2007.

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

Table 3a continued.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total
2003 Season, 38 days, Jan 15 - Feb 27, Fridays off								
Maine		773	1,020				49	1,842
Mass.		35	39					74
N.H.		82	159					241
Total		890	1,218				49	2,157
2004 Season, 40days, Jan 19 - Mar 12, Saturdays and Sundays off								
Maine	7	601	949	373	21	14	3	1,968
Mass.		9	32	8				49
N.H.		49	143	69				261
Total	7	659	1,124	450	21	14	3	2,278
2005 Season, 70 days, Dec 19 - 30, Fri-Sat off, Jan 3 - Mar 25, Sat-Sun off								
Maine	147	667	944	798				2,556
Mass.	13	20	61	26				120
N.H.	26	86	224	76				412
Total	186	773	1,229	900				3,088
***2006** Season, 140 days, Dec 12 - Apr 30								
Maine	139	523	617	262	82			1,623
Mass.	10	12	15	13				50
N.H.	8	28	23	58	10			127
Total	157	563	655	333	92			1,800
***2007** Season, 151 days, Dec 1 - Apr 30								
Maine	352	733	700	273	103	1		2,162
Mass.	3	1	8	7				19
N.H.	24	79	65	16	27			211
Total	379	813	773	296	130	1		2,392

* Preliminary data

Table 3b. Distribution of fishing trips in the Maine northern shrimp fishery by gear type and month, 2001 – 2007.

	Dec	Jan	Feb	Mar	Apr	May	Other	Season Total	% of total
2001									
Trawl		1,531	1,230	116	39	6		2,922	83%
Trap		191	347	68	1			607	17%
Total		1,722	1,577	184	40	6		3,529	
2002									
Trawl			573	221			14	808	77%
Trap			193	55				248	23%
Total			766	276			14	1,056	
2003									
Trawl		773	1,020				49	1,842	72%
Trap		253	466					719	28%
Total		1,026	1,486					2,561	
2004									
Trawl	7	601	949	373	21	14	3	1,968	82%
Trap		77	244	106	0	0	0	427	18%
Total	7	678	1,193	479	21	14	3	2,395	
2005									
Trawl	147	667	944	798				2,556	75%
Trap	0	20	363	483				866	25%
Total	147	687	1,307	1,281				3,422	
***2006**									
Trawl	139	523	617	262	82			1,623	66%
Trap	3	106	430	279	10			828	34%
Total	142	629	1,047	541	92			2,451	
***2007**									
Trawl	352	733	700	273	103	1		2,162	75%
Trap	22	99	381	209	3	0		714	25%
Total	374	832	1,081	482	106	1		2,876	

* preliminary data

Table 4. Stratified* mean numbers and weights per tow of northern shrimp collected during *R/V Gloria Michelle* state/federal summer surveys, 1984 - 2007.

		Log_e transformed				
Year	N Tows	Age-1.5 Number	>22 mm** Number	>22 mm** Weight (kg)	Total Number	Total Weight (kg)
1984		18	316	3.4	1,152	10.5
1985	44	337	1,184	11.7	1,849	17.7
1986	40	358	860	10.0	1,695	19.6
1987	41	342	854	9.5	1,533	14.8
1988	41	828	298	3.4	1,269	12.8
1989	43	276	564	6.1	1,883	17.0
1990	43	142	1,127	12.0	1,624	18.1
1991	43	482	657	8.0	1,255	11.7
1992	45	282	397	4.8	955	9.4
1993	46	757	250	2.8	1,156	9.1
1994	43	368	243	2.7	984	8.7
1995	35	292	628	7.0	1,449	13.3
1996	32	232	358	4.0	776	8.8
1997	40	374	245	2.8	762	7.7
1998	35	134	170	1.9	583	6.3
1999	42	114	174	1.9	398	5.8
2000	35	450	283	3.2	807	6.4
2001	36	18	146	1.5	451	4.3
2002	38	1,164	261	2.9	1,446	9.2
2003	37	11	173	1.7	564	5.5
2004	35	286	519	5.3	887	10.2
2005	46	1,753	871	10.3	3,661	23.3
2006	29	374	2,772	29.9	9,996	66.0
2007	43	24	344	3.4	741	10.9
Mean	40	392	571	6.3	1,578	13.6
Median	41	315	351	3.7	1,154	10.4

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

Table 5. Summary of results from CSA analysis, Gulf of Maine northern shrimp.

Fishing Season	New Recruits (millions)	Fully-Recruited (millions)	F (NR+FR)	Biomass (1000 mt)	Exploitation Rate
1985	827	771	0.29	11.58	22%
1986	848	935	0.26	15.15	20%
1987	649	1,073	0.32	15.71	24%
1988	508	969	0.19	13.62	15%
1989	762	950	0.21	11.88	16%
1990	806	1,085	0.30	14.57	23%
1991	542	1,086	0.25	15.44	19%
1992	402	988	0.24	13.51	18%
1993	363	853	0.20	11.13	15%
1994	557	776	0.26	9.01	20%
1995	903	802	0.52	11.90	36%
1996	909	792	0.74	13.68	47%
1997	562	631	1.07	9.89	57%
1998	475	317	0.74	5.54	47%
1999	354	294	0.47	4.63	33%
2000	261	317	0.52	4.67	36%
2001	333	267	0.31	4.31	23%
2002	260	344	0.09	4.59	7%
2003	549	431	0.14	5.70	11%
2004	407	664	0.23	7.75	18%
2005	843	660	0.19	12.14	15%
2006	2,500	965	0.06	21.67	5%
2007	2,157	2,529	0.09	34.11	8%
2008	433	3,319		31.99	
Overall average			0.33	12.7	23%
1985-94 average			0.25	13.2	19%

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

	Input				Results			
Fishing Season	Fall (kg/tow)	Maine (kg/tow)	Summer (kg/tow)	Catch (mt)	Biomass (mt)	F	B/Bmsy	F/Fmsy
1968	3.20	45.80		5,708	46,760	0.13	1.61	0.70
1969	2.70	31.20		12,136	44,520	0.30	1.54	1.69
1970	3.70	40.80		11,330	36,730	0.34	1.27	1.90
1971	3.00	9.40		10,594	30,420	0.39	1.05	2.16
1972	3.30	7.00		11,224	24,970	0.52	0.86	2.92
1973	1.90	7.80		9,691	18,550	0.63	0.64	3.50
1974	0.80	4.90		8,024	12,900	0.79	0.45	4.44
1975	0.90	6.70		6,142	7,843	1.16	0.27	6.48
1976	0.60	4.80		1,387	3,413	0.43	0.12	2.38
1977	0.20	1.60		372	3,125	0.11	0.11	0.59
1978	0.40	3.20		17	3,931	0.00	0.14	0.02
1979	0.50	4.40		487	5,439	0.08	0.19	0.44
1980	0.50	2.70		339	6,913	0.04	0.24	0.24
1981	1.50	3.00		1,071	9,012	0.11	0.31	0.61
1982	0.30	2.00		1,530	10,870	0.13	0.38	0.73
1983	1.00	4.20		1,397	12,690	0.10	0.44	0.57
1984	1.90		10.50	2,951	15,050	0.19	0.52	1.06
1985	1.60		17.70	4,131	16,160	0.26	0.56	1.43
1986	2.50		19.60	4,635	16,190	0.29	0.56	1.63
1987	1.70		15.40	5,253	15,680	0.35	0.54	1.96
1988	1.20		12.80	3,031	14,390	0.20	0.50	1.14
1989	1.81		17.00	3,315	15,300	0.21	0.53	1.19
1990	2.04		18.10	4,665	16,070	0.30	0.55	1.66
1991	0.94		11.70	3,571	15,500	0.23	0.53	1.27
1992	0.95		9.40	3,444	16,020	0.21	0.55	1.18
1993	0.57		9.10	2,143	16,780	0.12	0.58	0.67
1994	1.86		8.70	2,915	19,040	0.15	0.66	0.82
1995	2.26		13.30	6,466	20,790	0.33	0.72	1.83
1996	1.64		8.80	9,166	18,980	0.56	0.66	3.15
1997	1.17		7.70	7,079	13,980	0.59	0.48	3.30
1998	1.35		6.30	4,174	10,290	0.43	0.36	2.43
1999	2.26		5.80	1,816	8,981	0.19	0.31	1.07
2000	2.39		6.40	2,389	9,994	0.23	0.34	1.30
2001	1.43		4.30	1,329	10,630	0.12	0.37	0.64
2002	0.63		9.20	424	12,610	0.03	0.44	0.17
2003	1.70		5.45	1,211	16,010	0.07	0.55	0.39
2004	1.08		10.23	1,948	19,170	0.10	0.66	0.53
2005	1.58		23.29	2,561	21,950	0.11	0.76	0.62
2006	2.77		65.95	2,087	24,340	0.08	0.84	0.45
2007	6.64		10.87	3,374	27,360	0.12	0.94	0.67
2008					29,150		1.01	
Average	**1.7**			**4,138**	**17,037**	**0.27**		
				1971-74 average	21,710	0.58		
				1985-94 average	16,113	0.23		
				2005-07 average	24,550	0.10		

Table 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

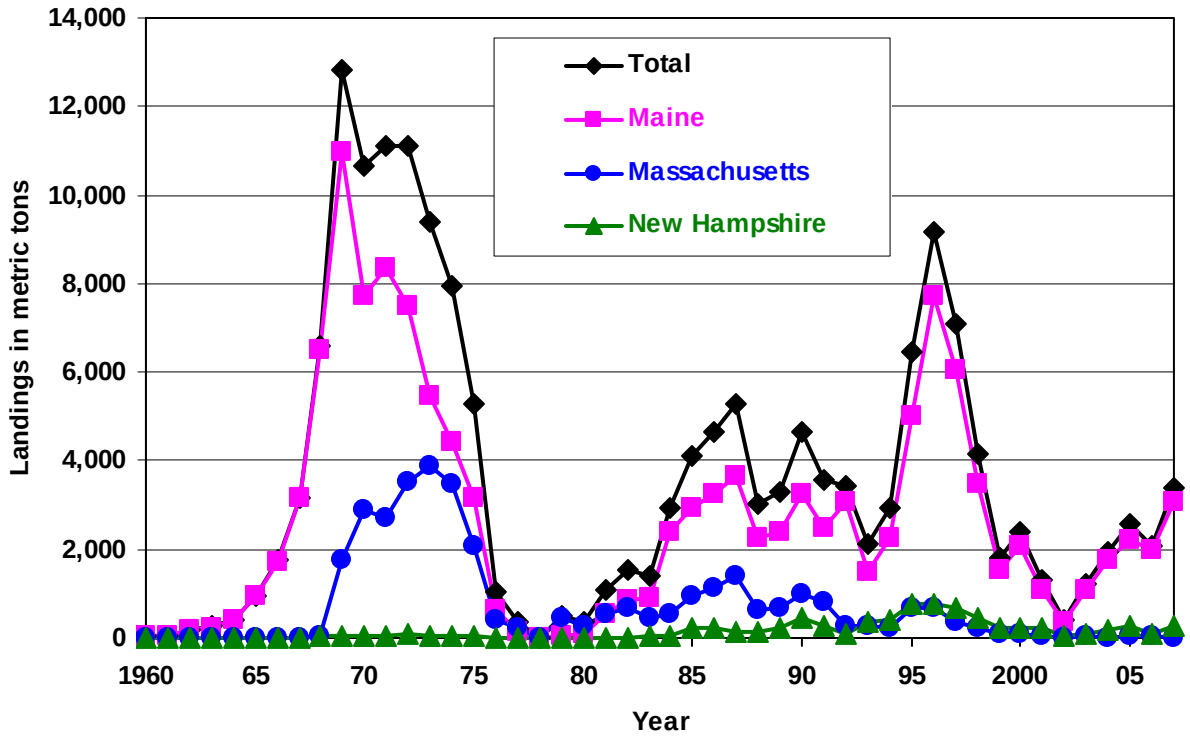


Figure 1a. Gulf of Maine northern shrimp landings by year and state.

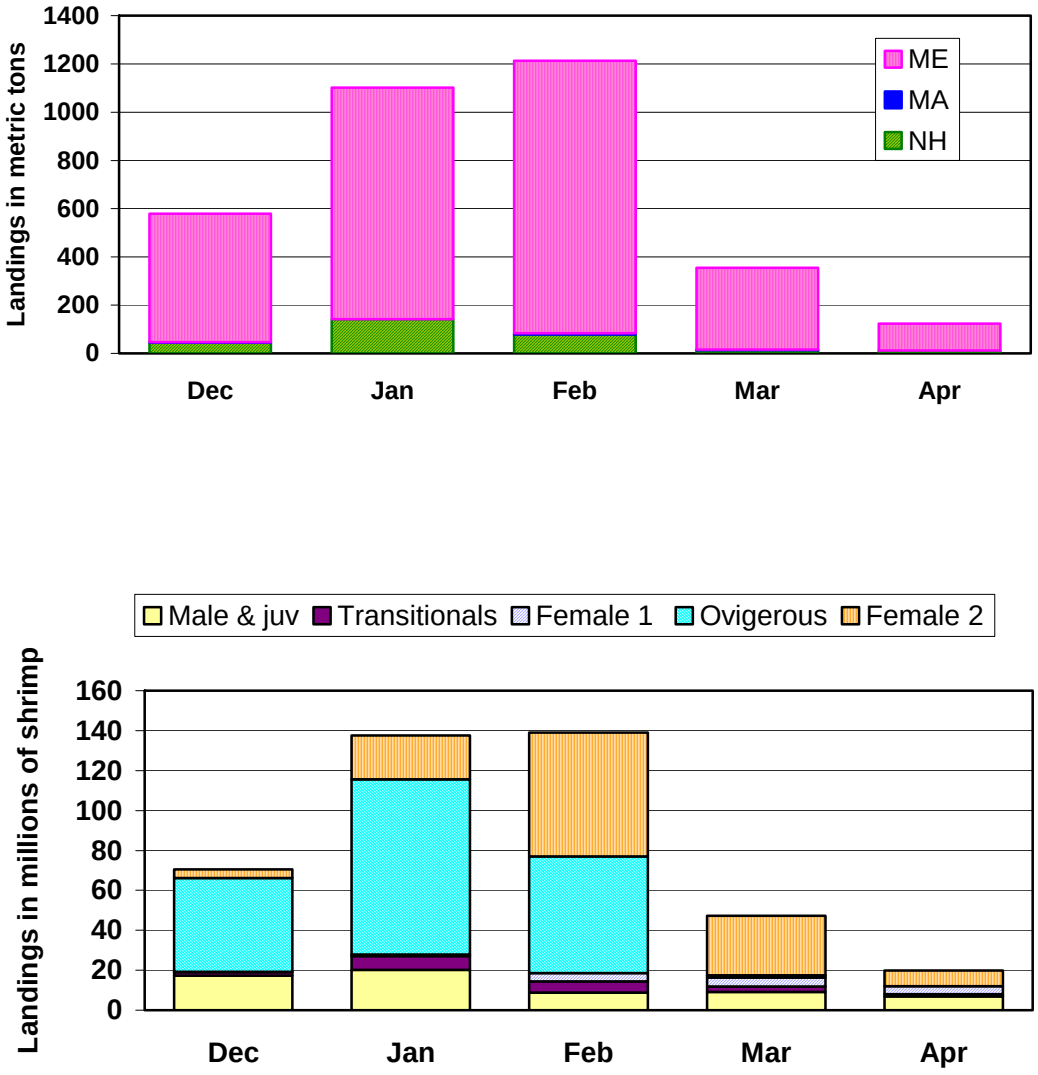


Figure 1b. **Gulf of Maine northern shrimp landings by month in the 2007 season. Landings are in metric tons by month (above), and in millions of shrimp by development stage (below).**

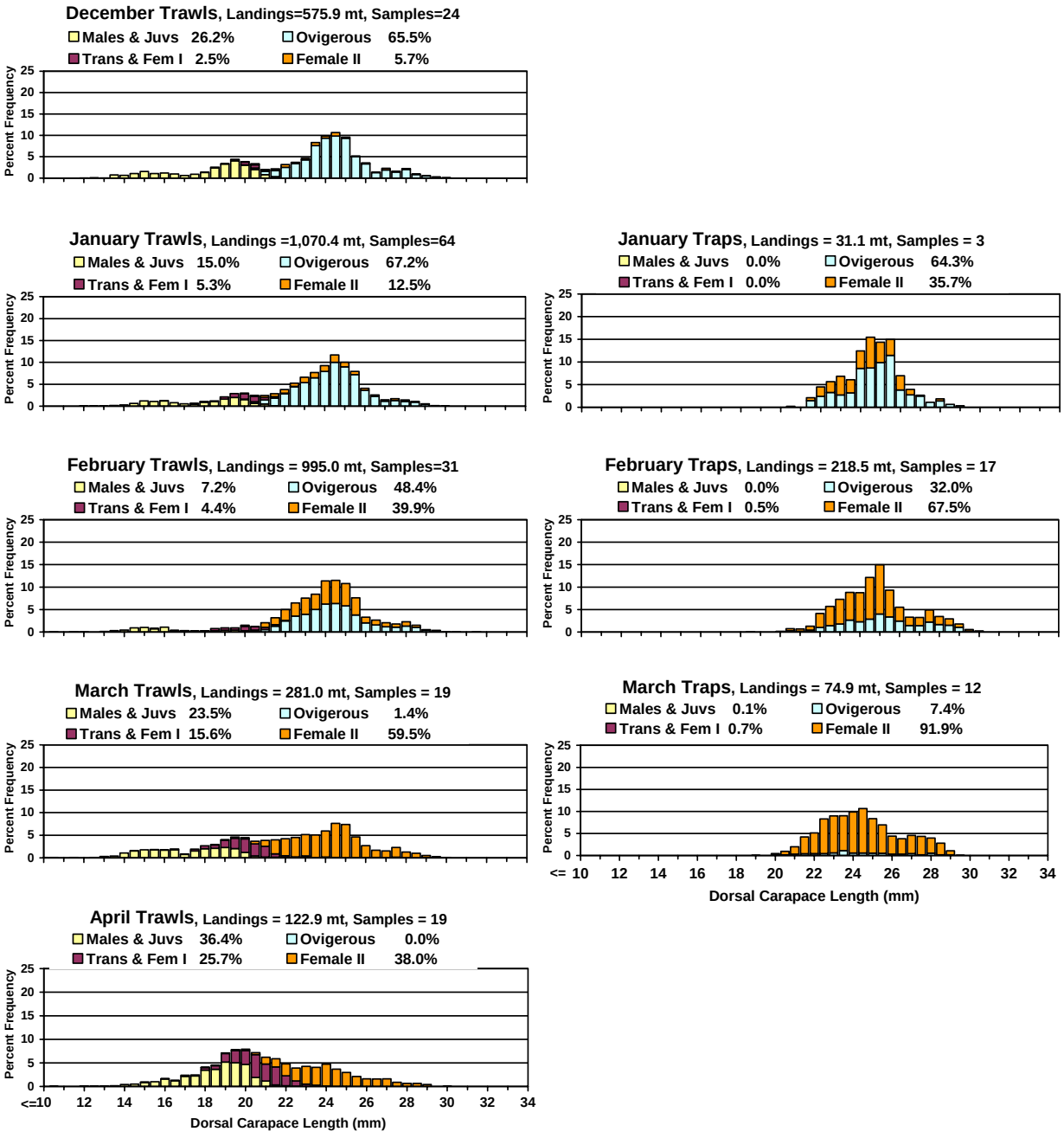


Figure 2. Length-frequency distribution from samples of Maine northern shrimp catches during the 2007 season. Landings are preliminary.

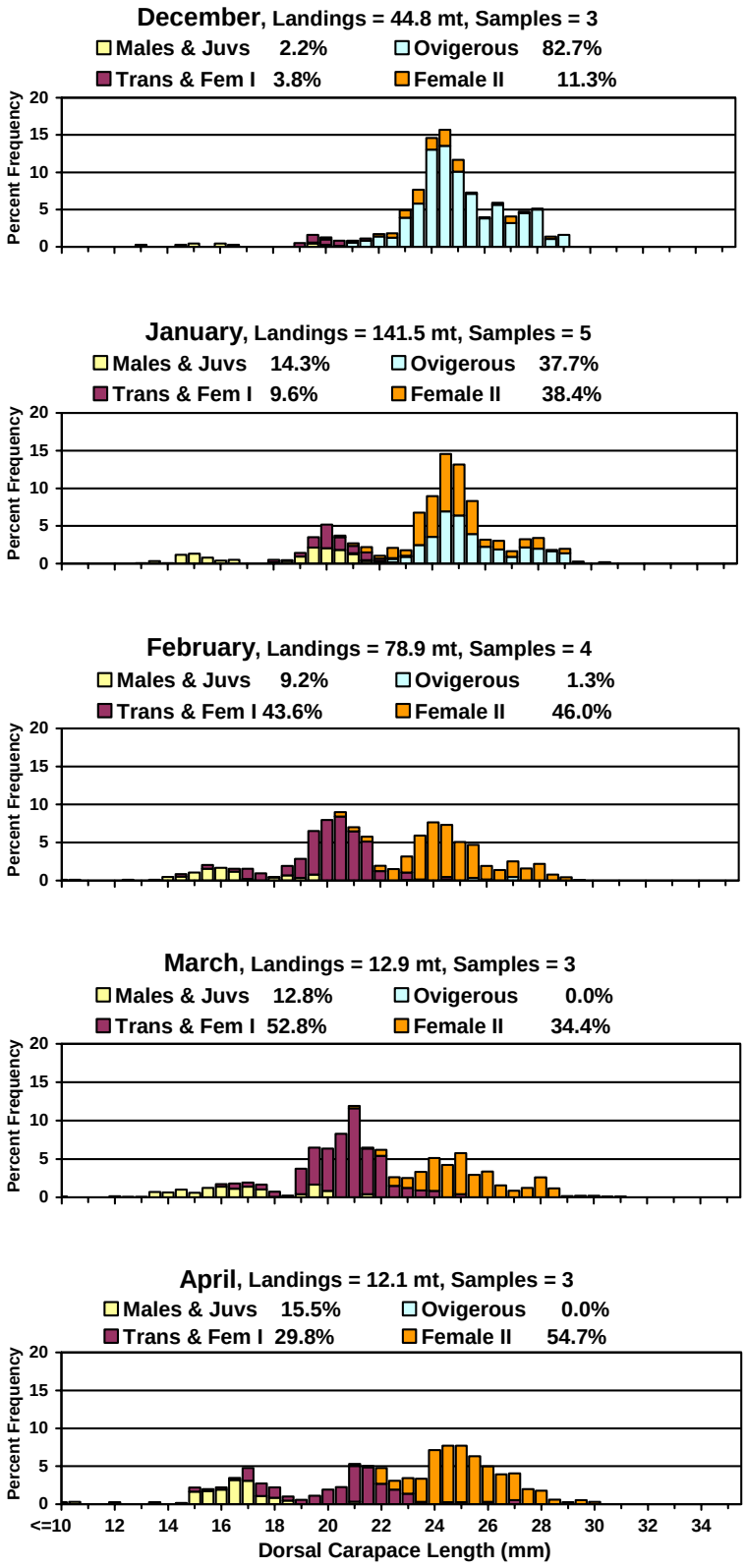


Figure 3. Length-frequency distribution from samples of New Hampshire northern shrimp catches during the 2007 season. Landings are preliminary.

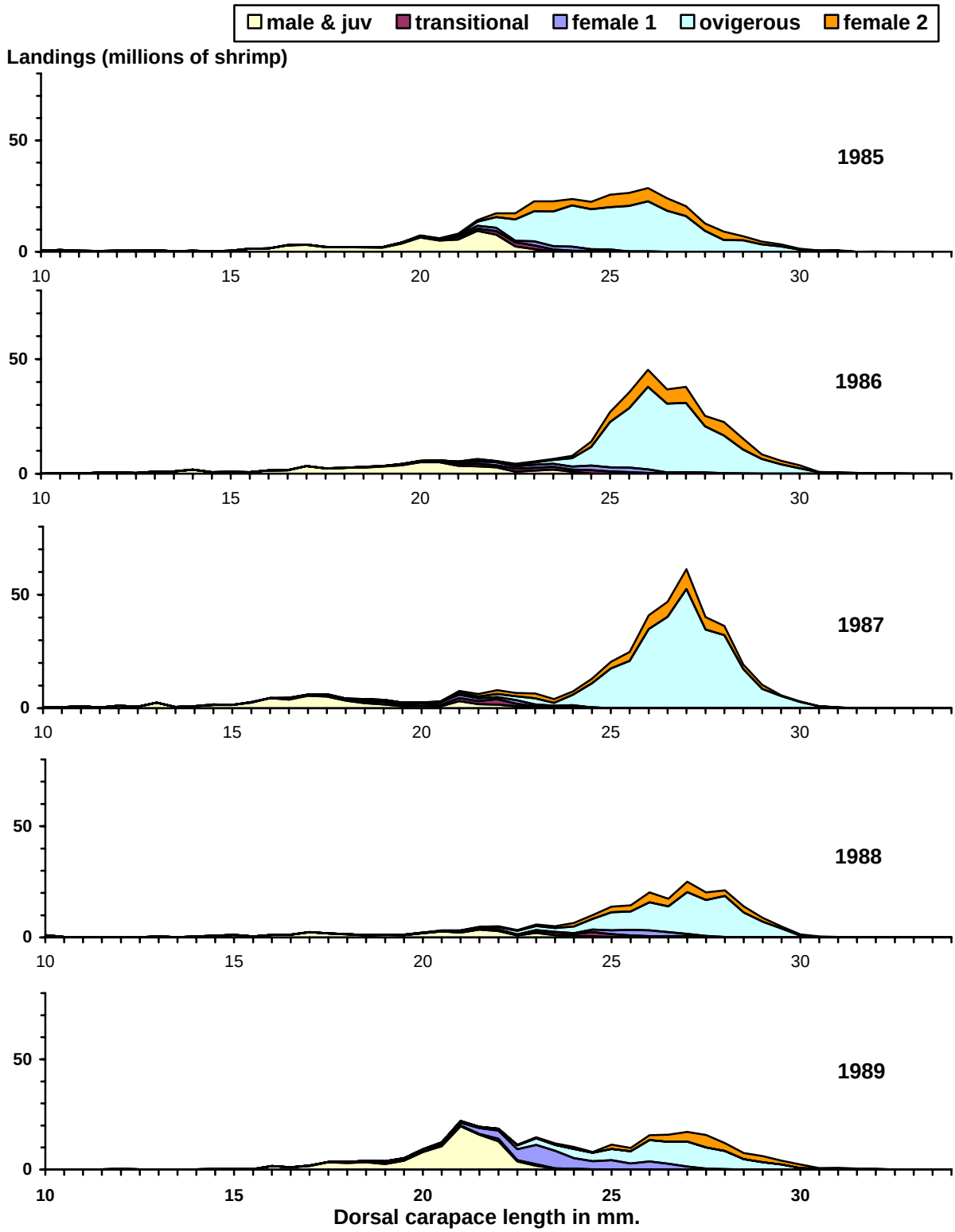


Figure 4. Gulf of Maine northern shrimp landings by length, development stage, and fishing season. Landings are preliminary throughout.

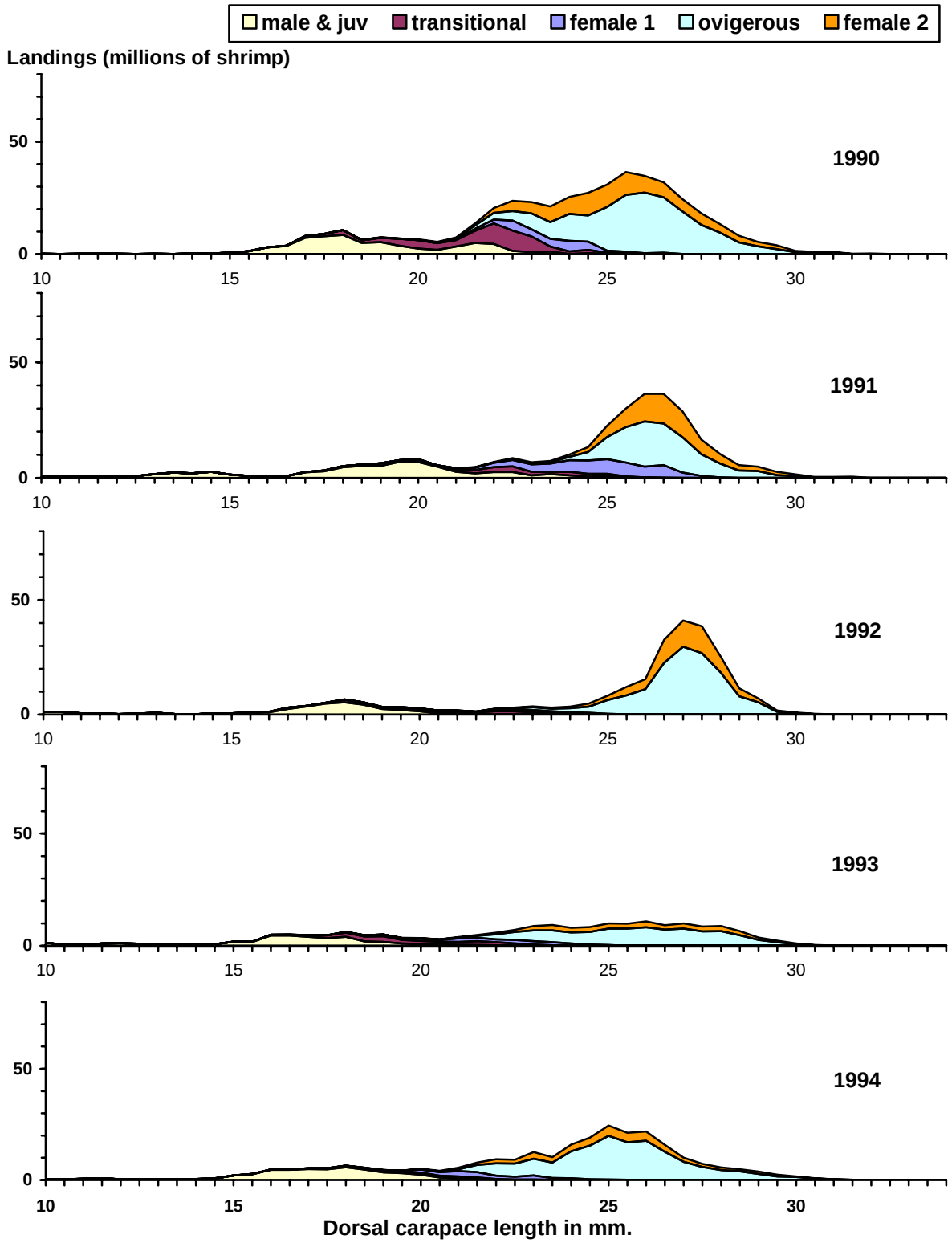


Figure 4 continued.

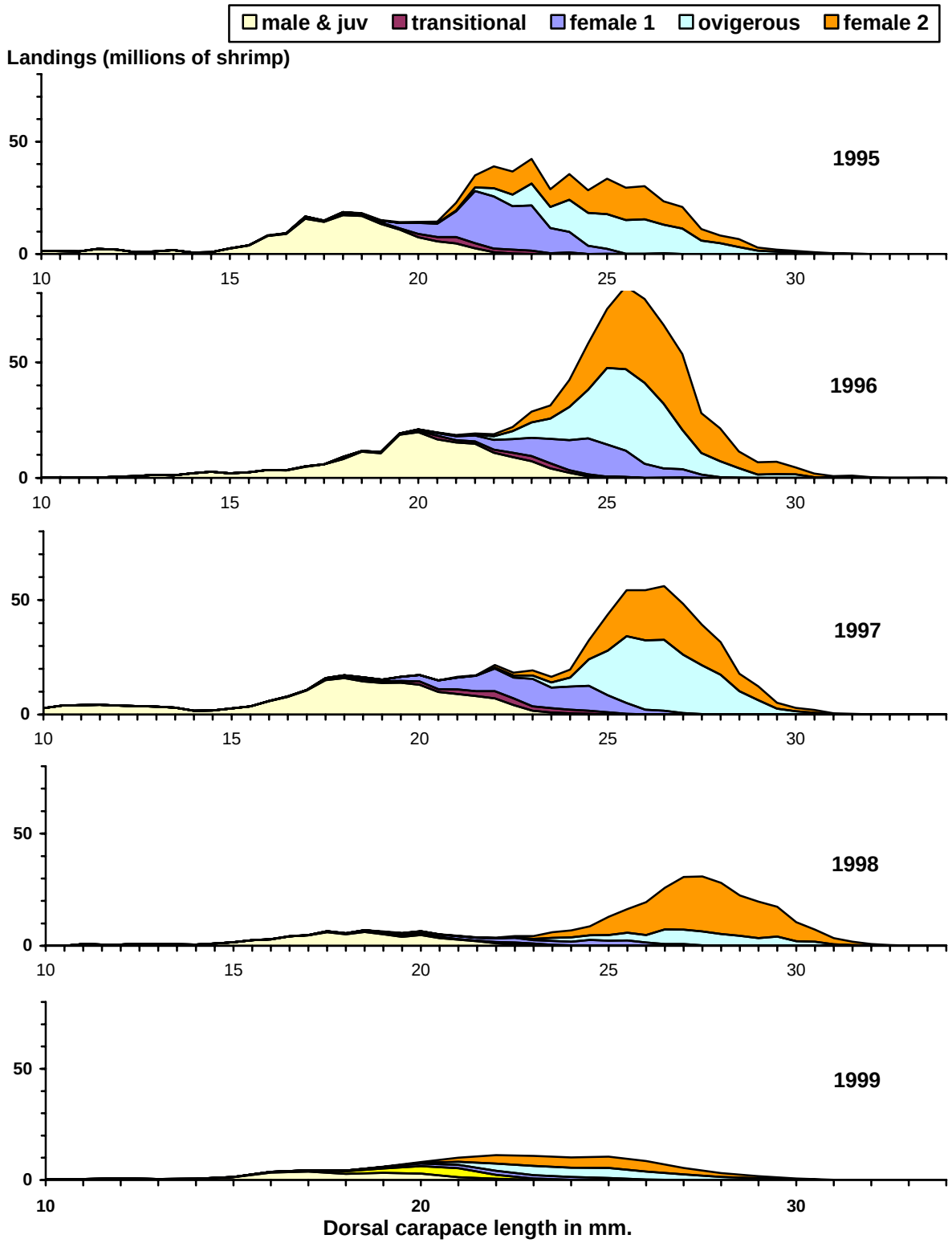
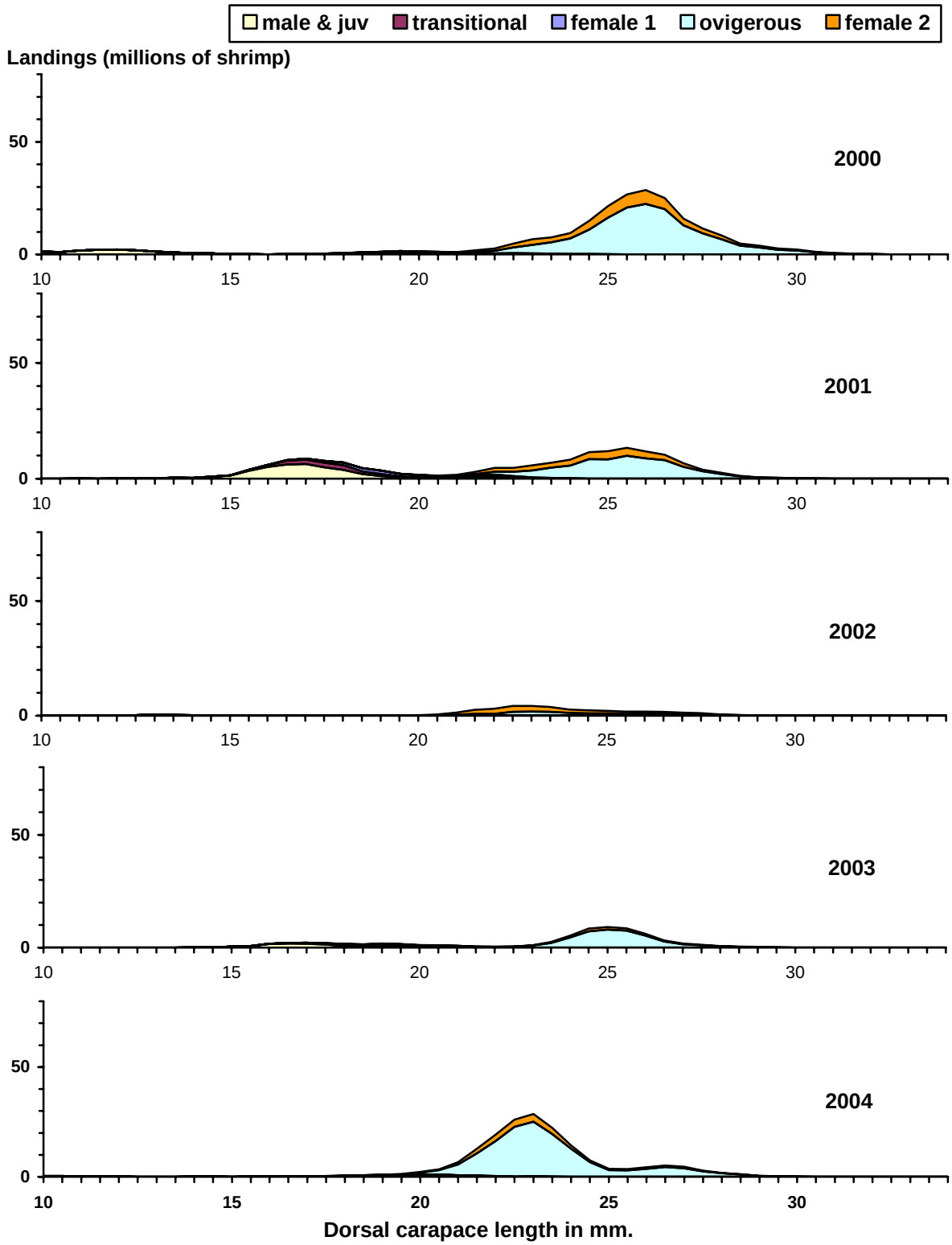


Figure 4 continued.



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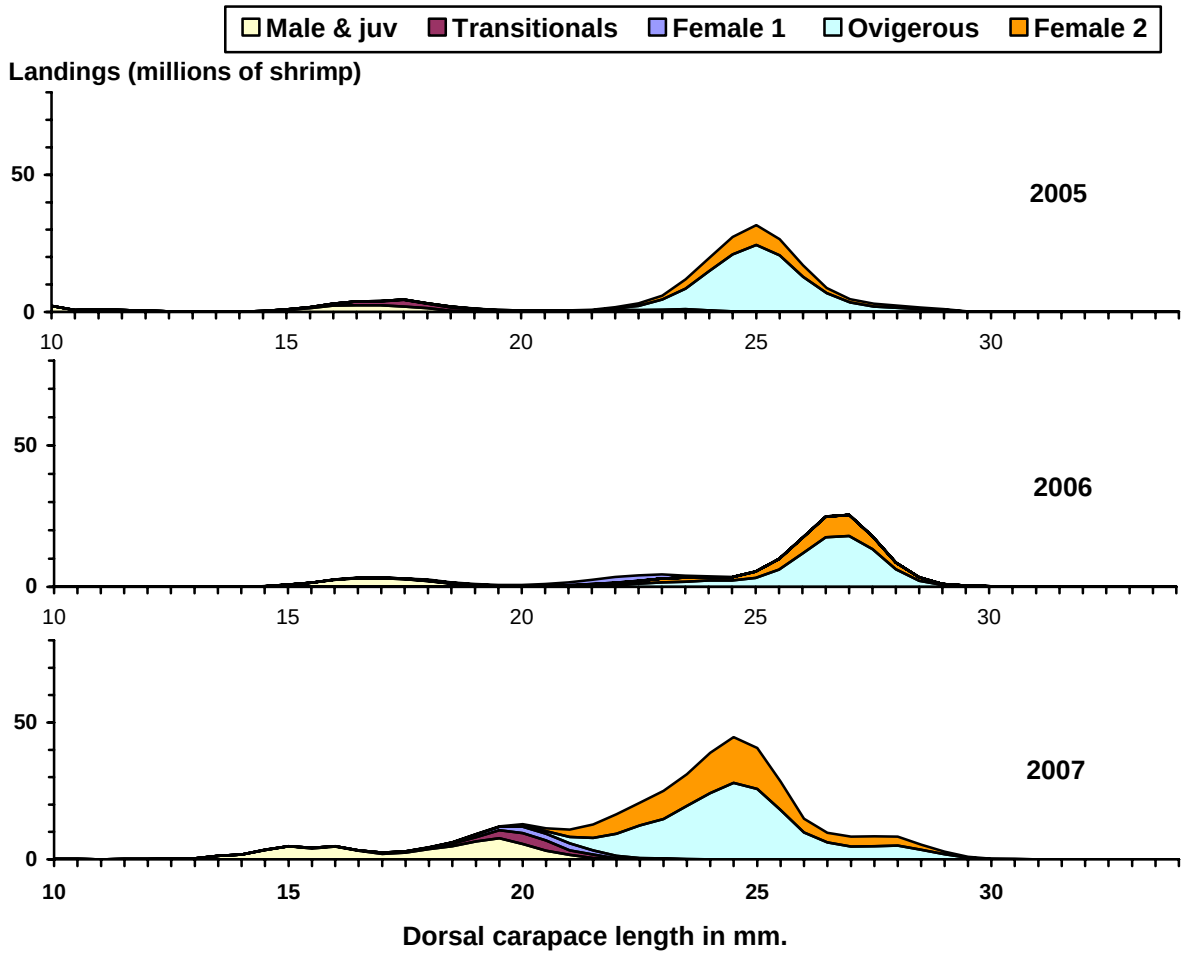

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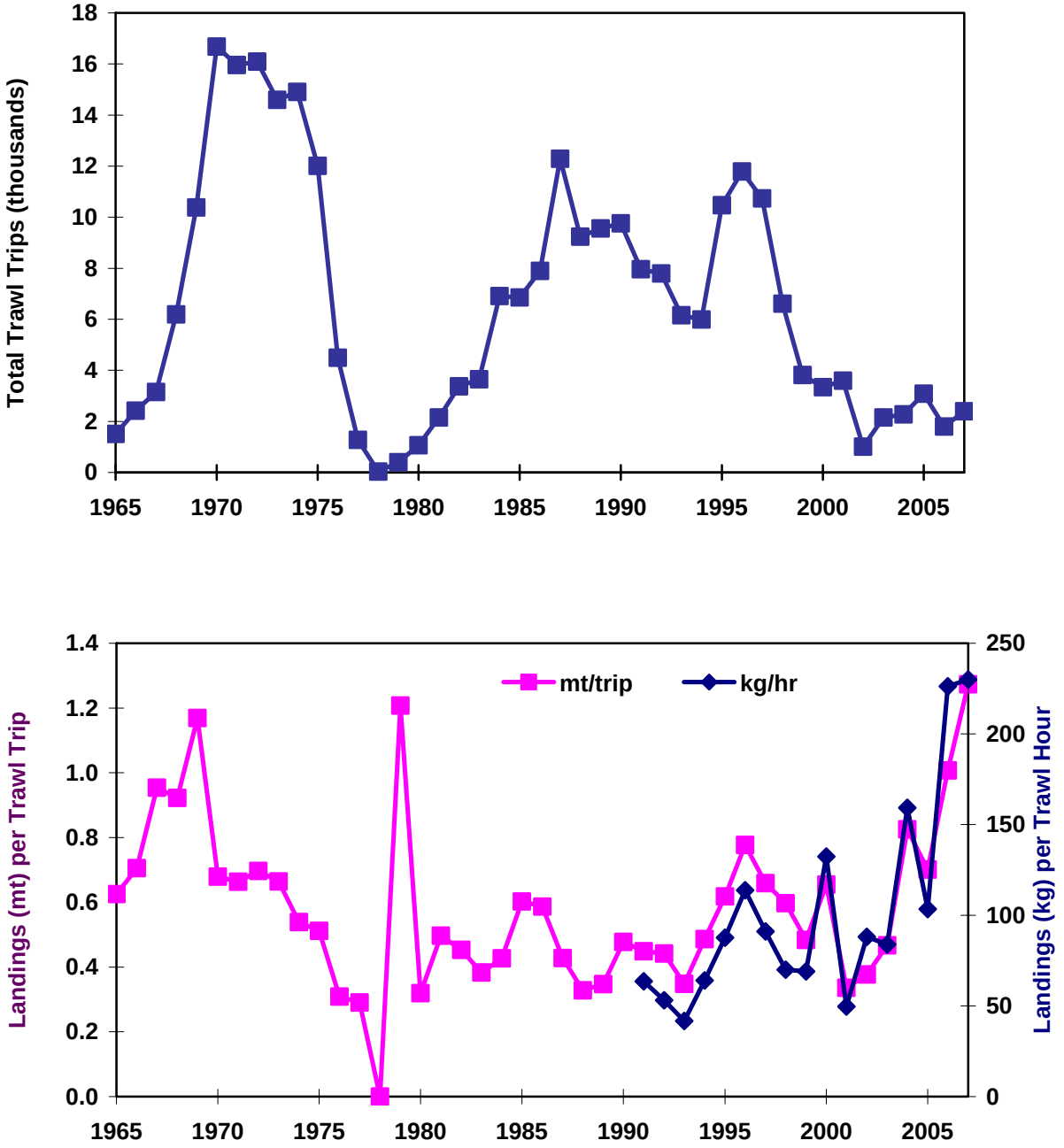


Figure 5. Nominal fishing effort (trawl trips) (above) and catch per unit effort (below), in the Gulf of Maine northern shrimp fishery by year. 2006 and 2007 data are preliminary.

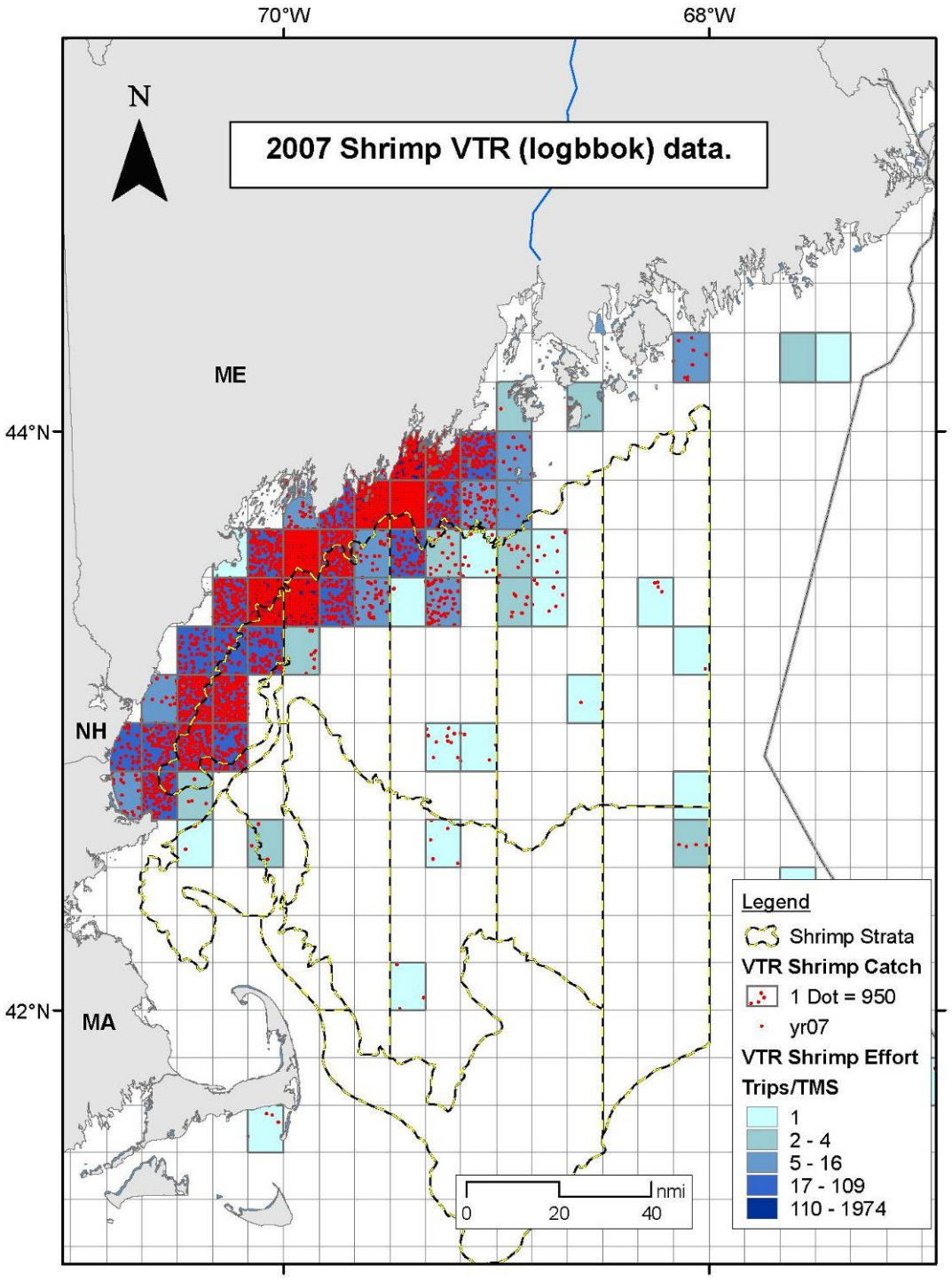


Figure 6a. Pounds caught and numbers of trips during the 2007 northern shrimp fishing season by 10-minute-square. Each red dot represents 950 lbs caught; locations of dots within squares are random. Number of trips is indicated by the blue palette for the squares. From harvester logbook (VTR) data. Does not include Maine non-federally-permitted vessel trips and catches.

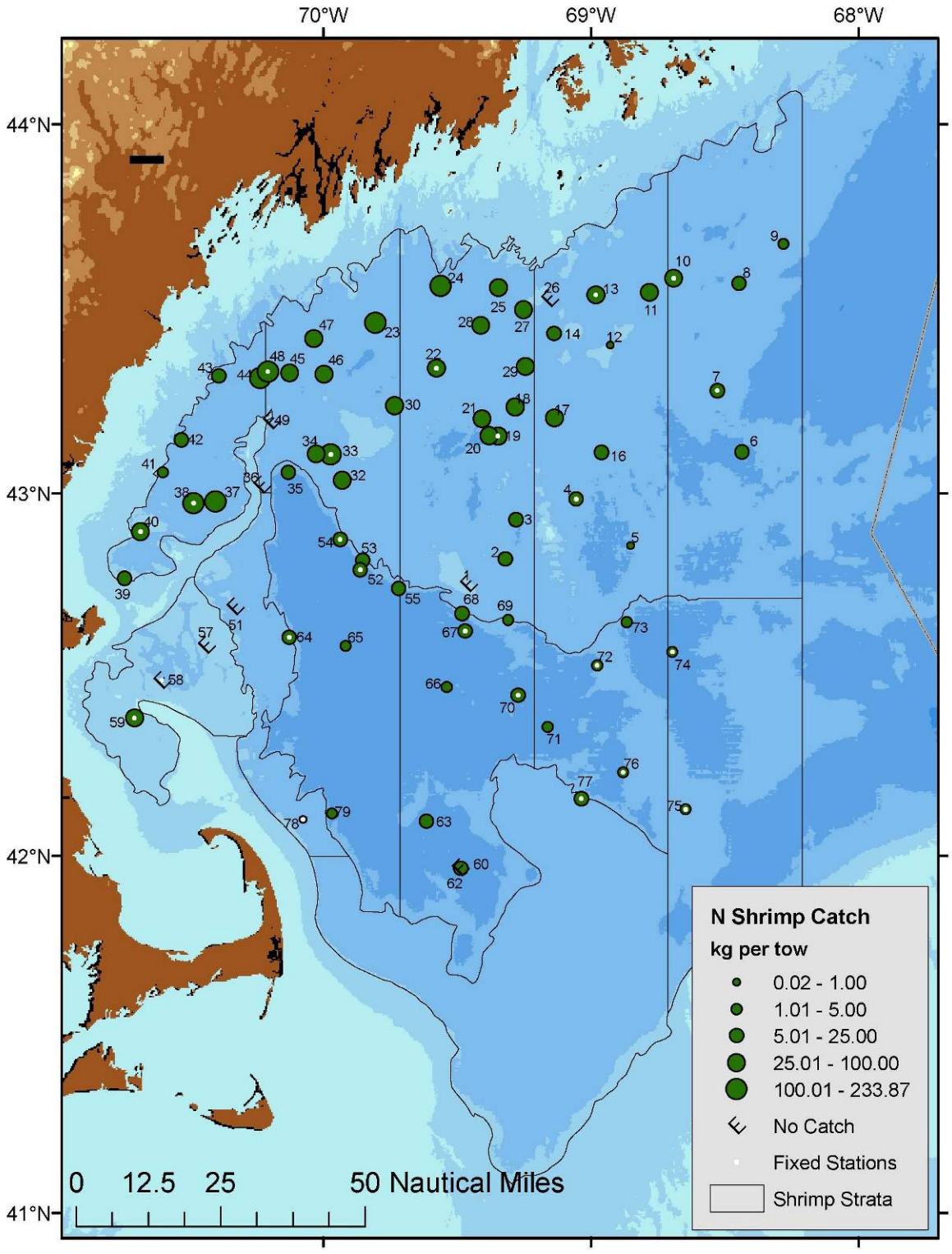


Figure 6b. State/federal northern shrimp survey aboard the R/V Gloria Michelle, July 22 – August 18, 2007; statistical strata and survey sites with catches (kg/tow).

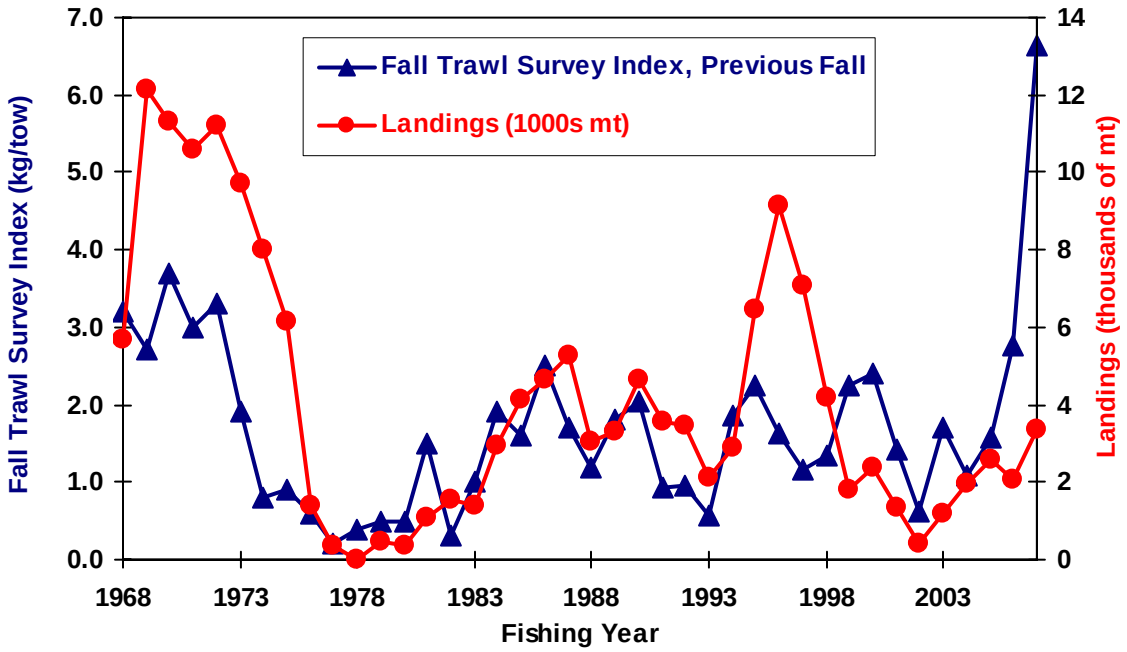


Figure 7. Fall trawl survey index and Gulf of Maine northern shrimp landings the following season.

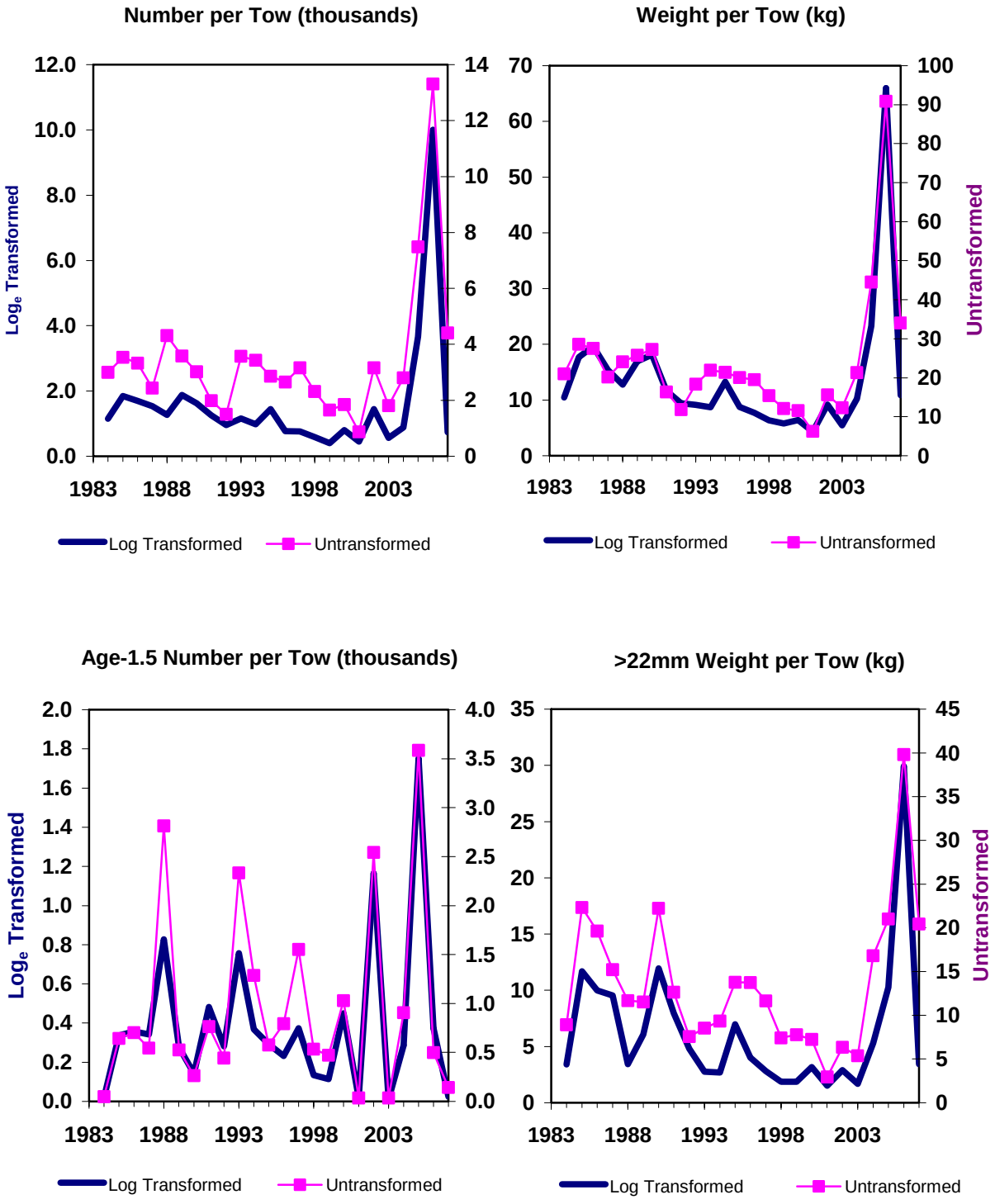


Figure 8. Gulf of Maine northern shrimp 2007 summer survey indices of abundance (left) and biomass (right), by survey year.

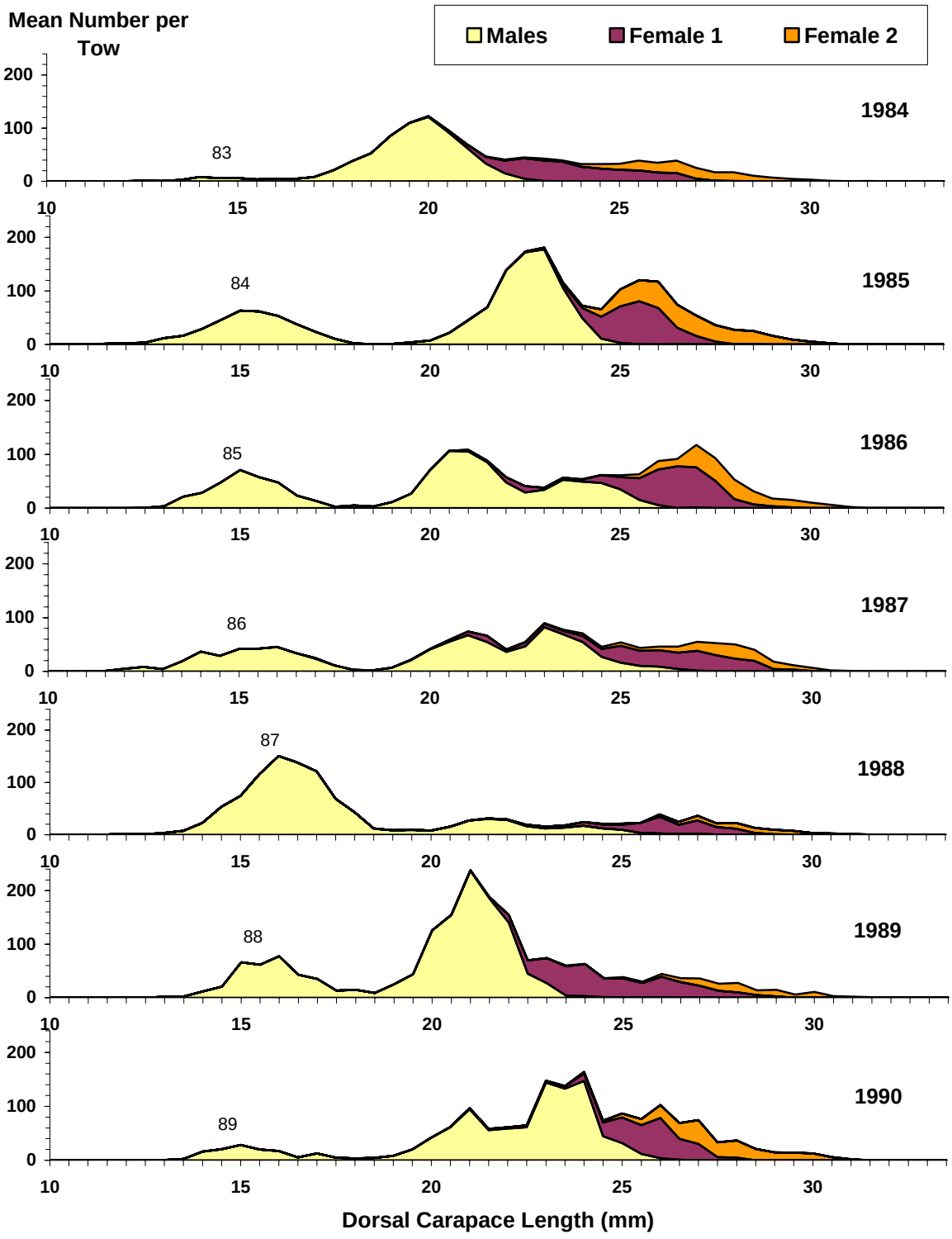


Figure 9. Gulf of Maine northern shrimp summer survey mean catch per tow by year, length, and development stage. Two-digit years are year class at assumed age 1.5.

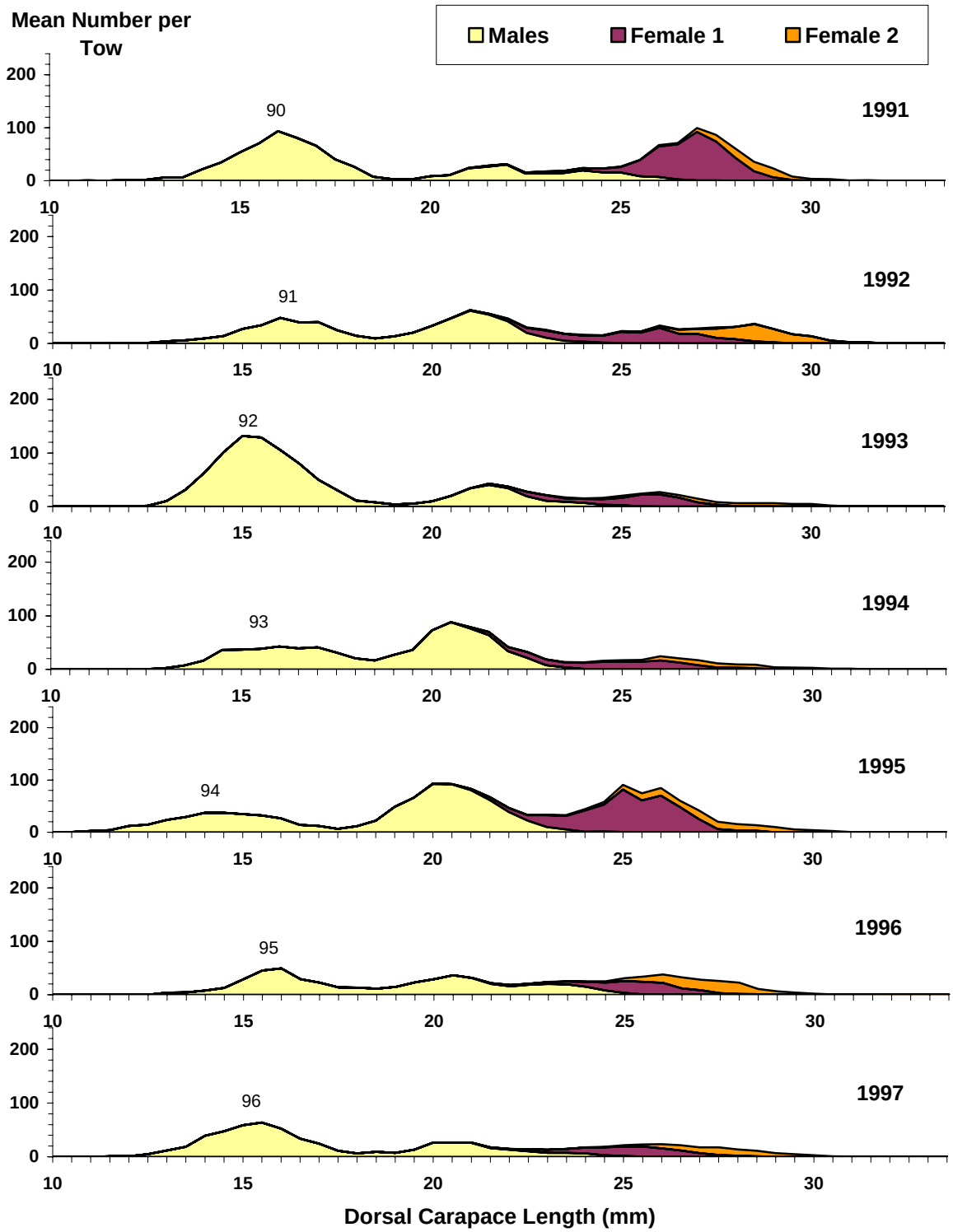


Figure 9 continued.

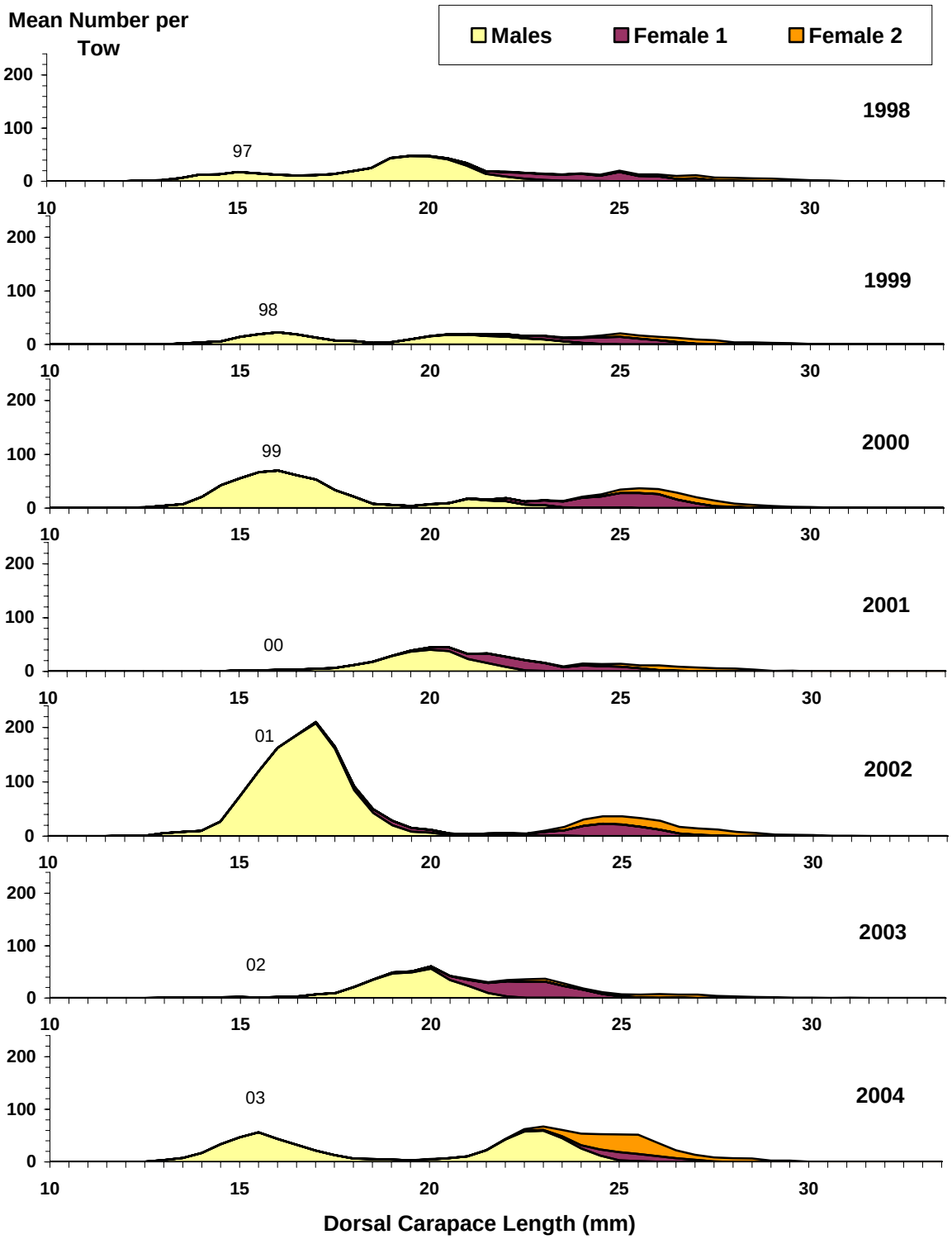


Figure 9 continued.

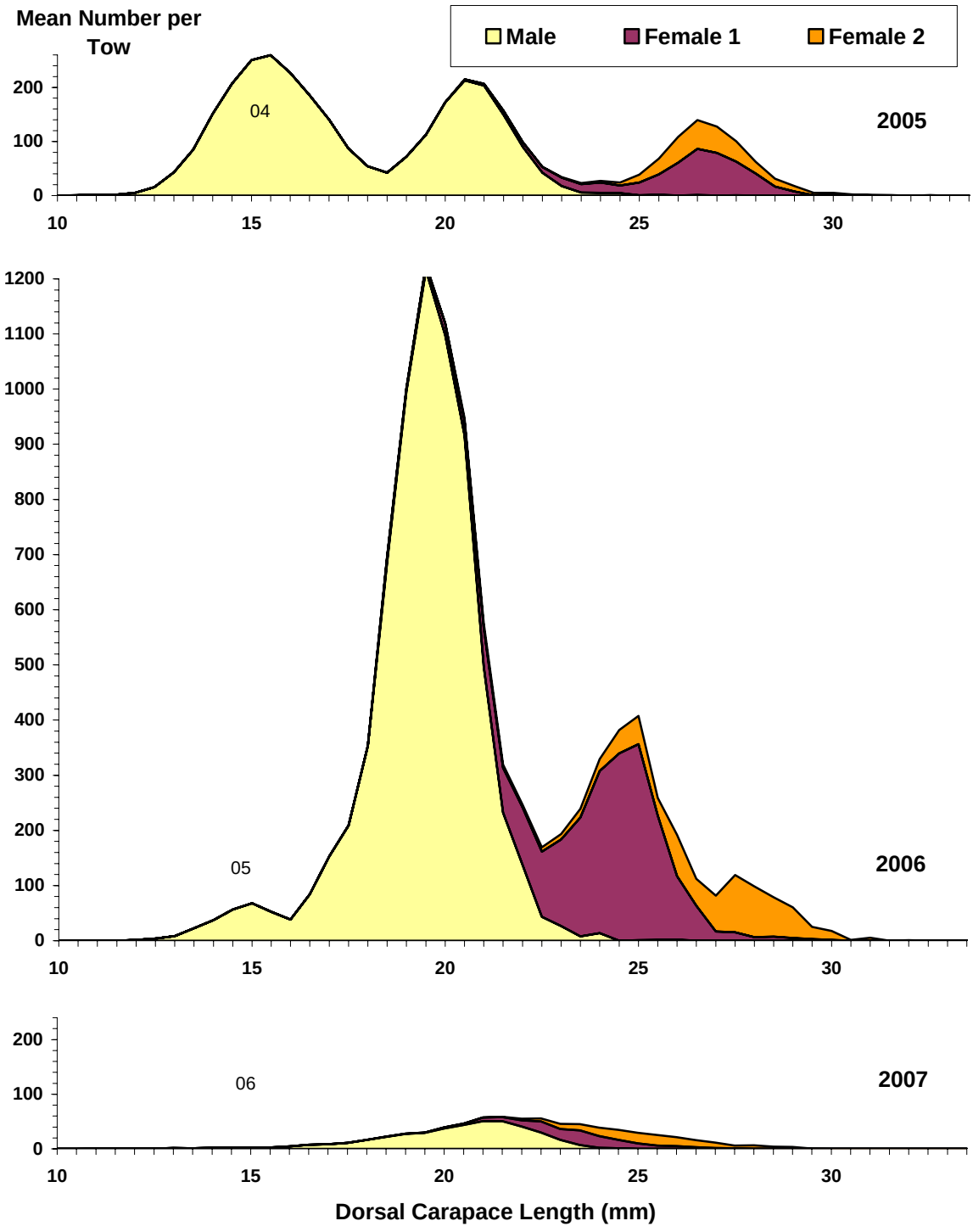


Figure 9 continued.

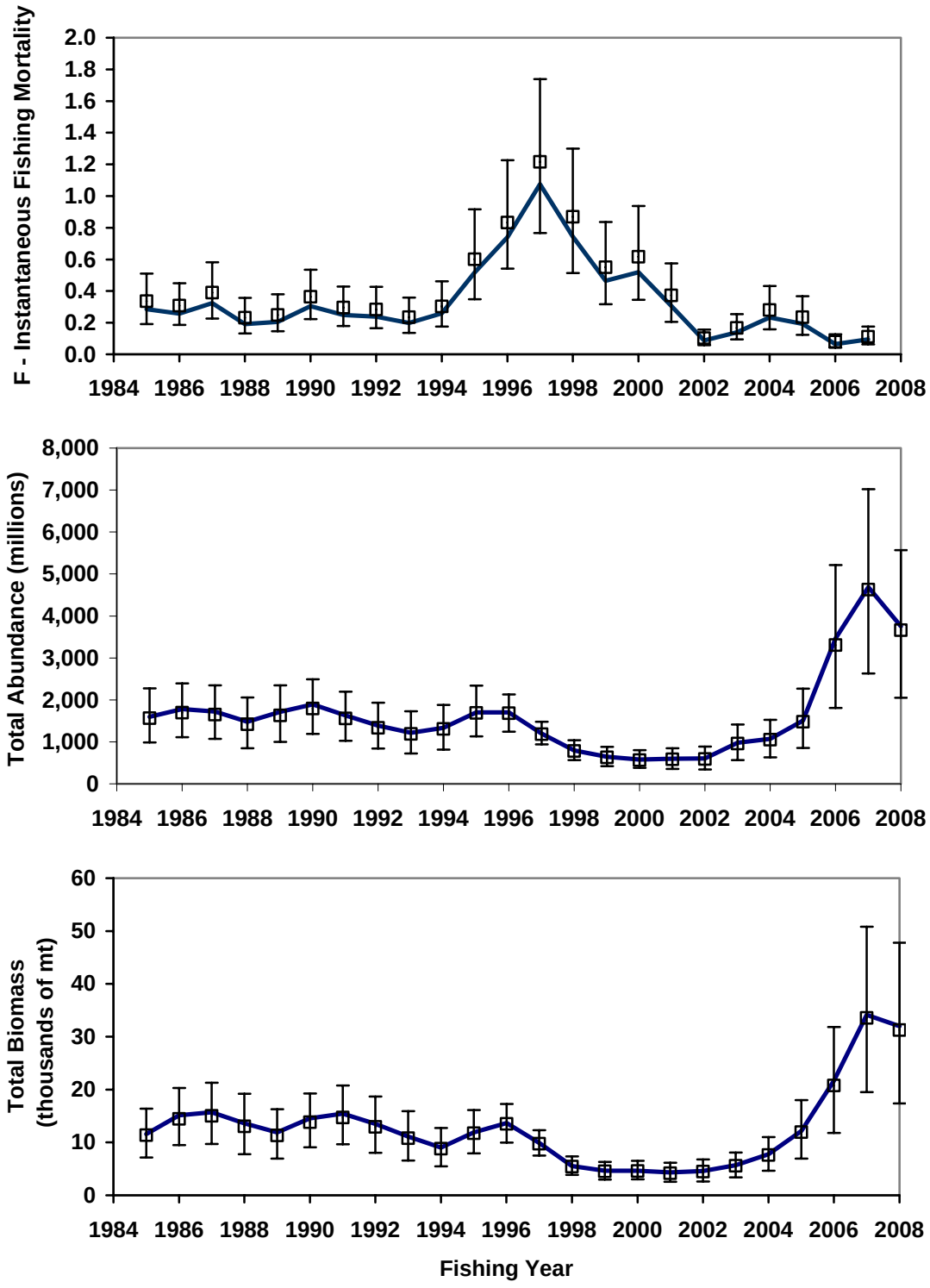


Figure 10. Fishing mortality, abundance, and biomass of Gulf of Maine northern shrimp as estimated by CSA, with least squares estimates, bootstrapped means (square symbols), and 80% confidence intervals.

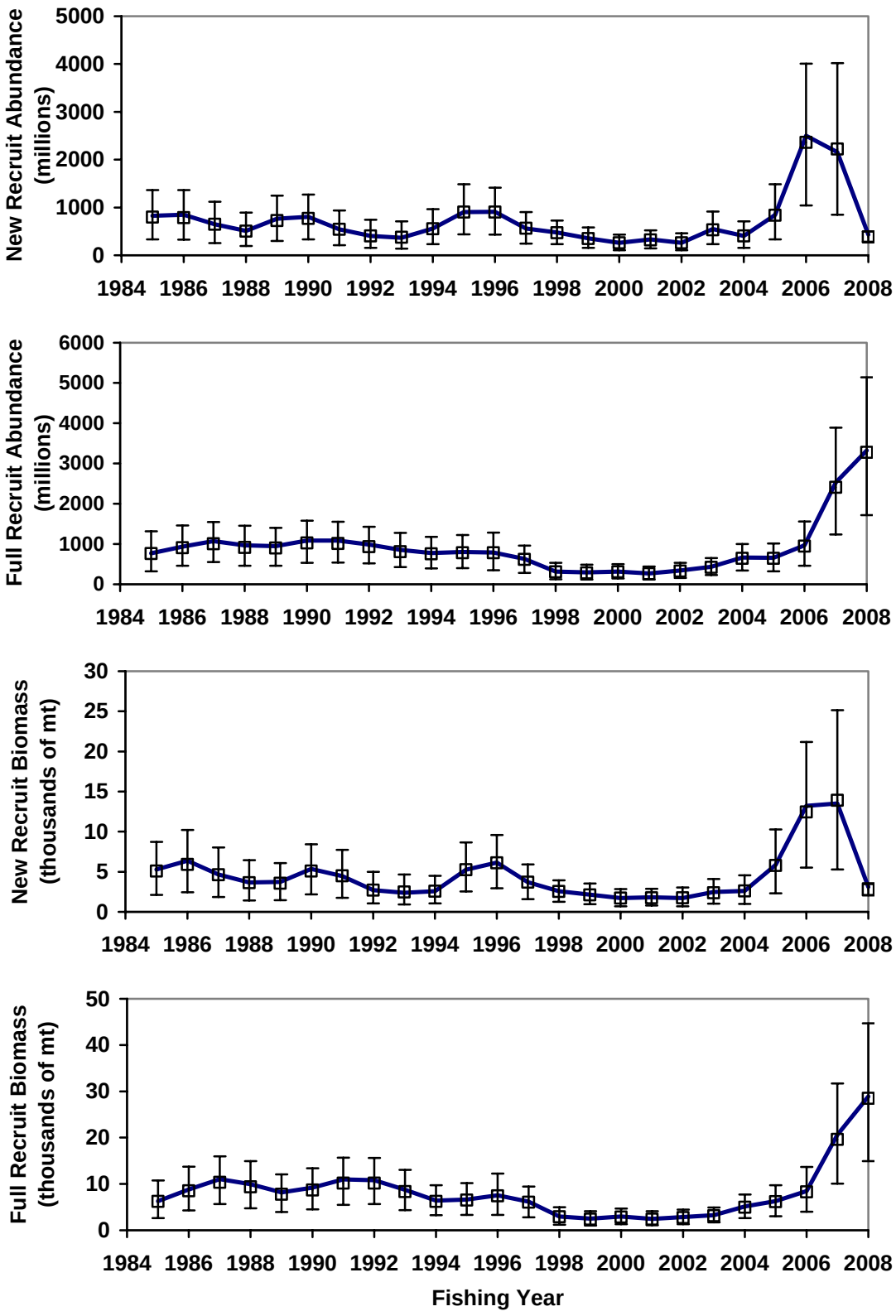


Figure 10 continued.

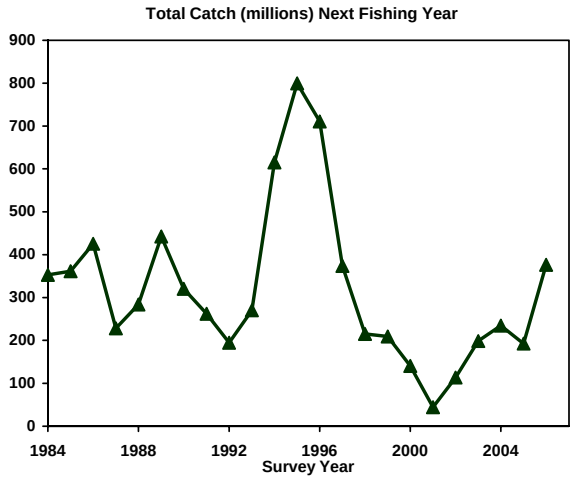
Input Data using Summer Survey			
Survey Year*	Indices of Abundance		Total Catch Millions*
	Recuits	Full Recruits	
1984	447.6	479.1	352.79
1985	619.5	925.4	361.17
1986	533.3	848.5	425.29
1987	482.9	766.9	228.43
1988	459.8	387.7	283.65
1989	701.1	817.9	442.43
1990	511.5	907.5	320.29
1991	374.3	612.1	262.43
1992	313.6	444.4	194.79
1993	410.2	320.8	270.41
1994	368.6	364.3	615.32
1995	485.8	653.3	799.37
1996	257.7	348.6	710.97
1997	257.3	267.1	373.68
1998	217.1	226.6	215.12
1999	137.4	174.6	209.28
2000	276.3	288.2	140.88
2001	171.8	196.4	44.40
2002	550.6	372.9	113.66
2003	222.9	229.9	198.74
2004	292.7	405.9	234.69
2005	1,295.2	1,231.7	192.84
2006	3,877.6	4,023.6	376.23
2007	270.5	351.7	

* Survey Year data are applied to the following Fishing Year

Results			
Stock Size Estimates millions at time of Survey		Fishing Mortality	Total Mortality
Recruits	Full Recruits	All sizes	Z all sizes
826.6	770.6	0.29	0.54
848.4	935.2	0.26	0.51
648.9	1,072.9	0.32	0.57
508.5	969.1	0.19	0.44
762.4	950.5	0.21	0.46
806.1	1,085.4	0.30	0.55
542.1	1,086.1	0.25	0.50
402.3	987.6	0.24	0.49
363.2	852.5	0.20	0.45
557.3	776.1	0.26	0.51
903.0	801.7	0.52	0.77
908.8	791.8	0.74	0.99
562.4	631.4	1.07	1.32
475.5	317.4	0.74	0.99
353.9	293.6	0.47	0.72
260.7	316.7	0.52	0.77
332.8	267.4	0.31	0.56
259.7	344.2	0.09	0.34
549.3	431.4	0.14	0.39
406.9	664.0	0.23	0.48
843.3	660.0	0.19	0.44
2500.3	965.0	0.06	0.31
2156.9	2,529.2	0.09	0.34
433.2	3,319.1		

Input File Name	R2007_BL.dat
Tuning Dataset	Survey
Time of Survey (yr)	0
Time of Catch (yr)	0
Natural Mortality Rate	0.25
Relative Catchability: Recruits to Full Recruits s_r	0.6 - 1.0
Catchability Estimate and CV	0.6939 0.2212

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 2007



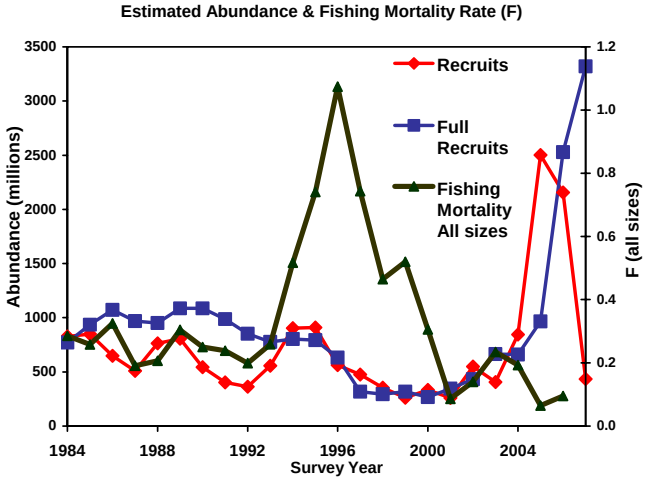


Figure 11. Catch-Survey model (CSA) input data and results.

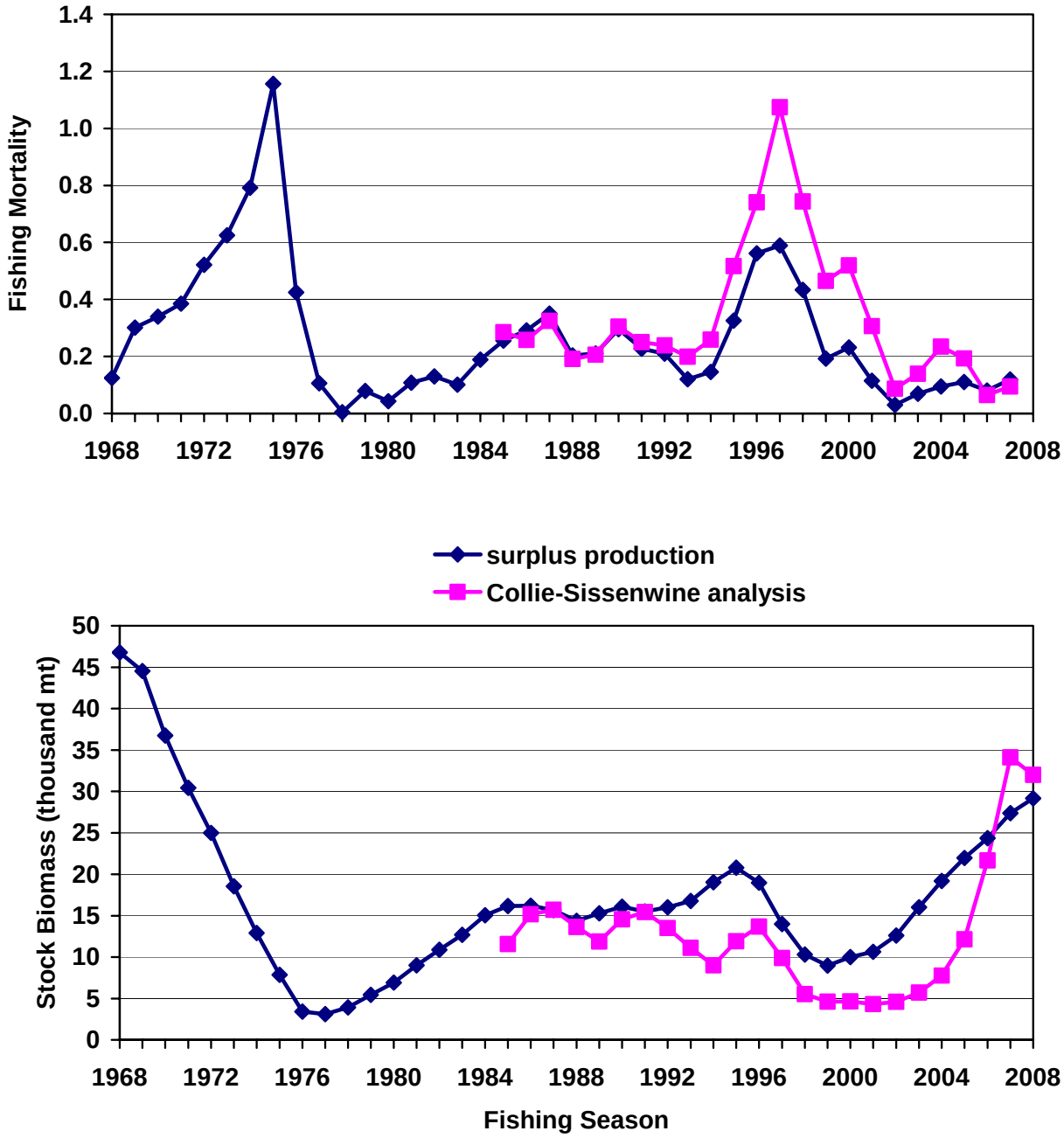


Figure 12. Estimates of fishing mortality (above) and stock biomass (below) for northern shrimp from Collie-Sissenwine analysis (CSA) and surplus production (ASPIC) modeling.

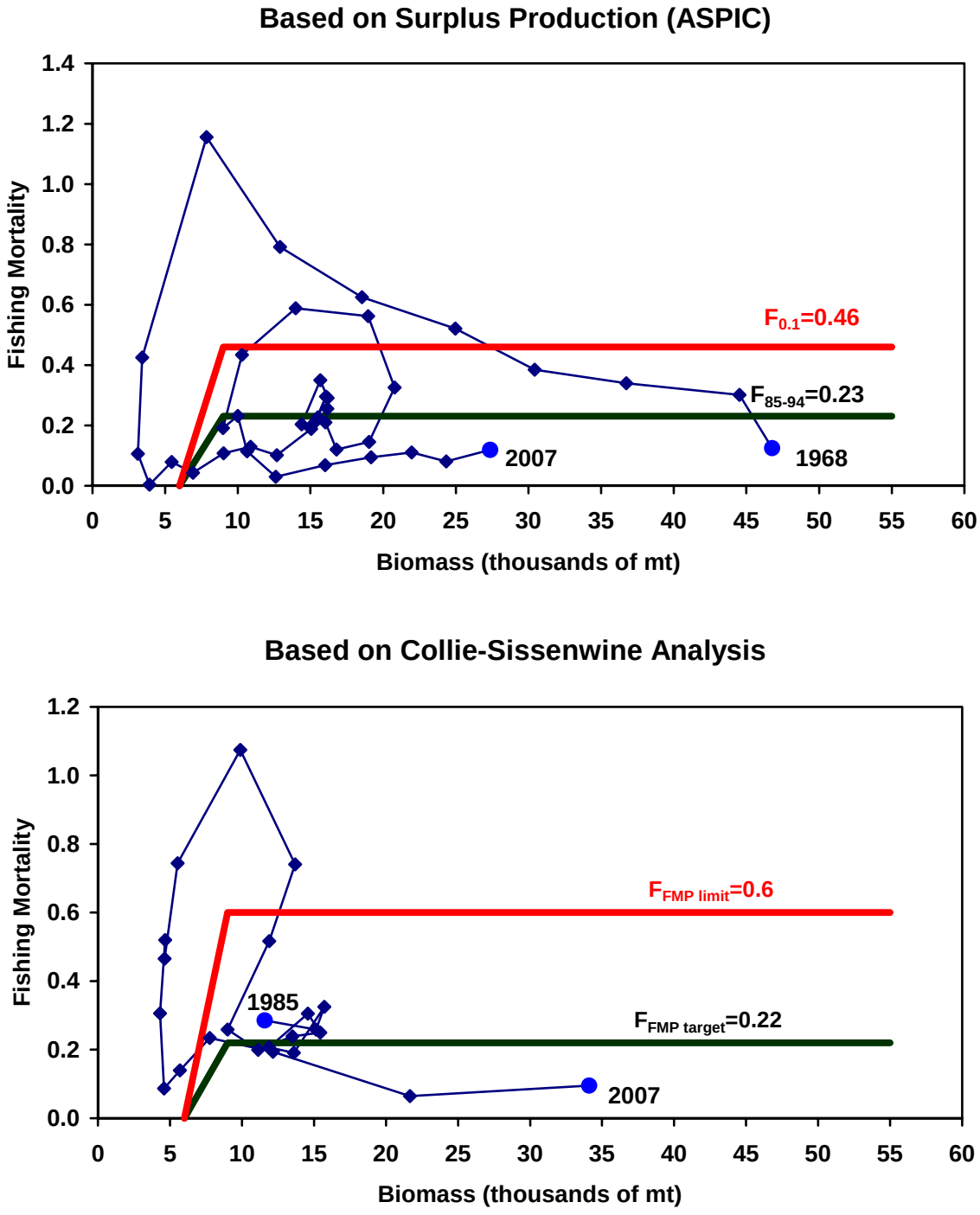


Figure 13. Biomass dynamics of the Gulf of Maine northern shrimp fishery, from surplus production (ASPIC) (above) and Collie-Sissenwine (CSA) (below) analyses, with possible fishing mortality and biomass reference points.

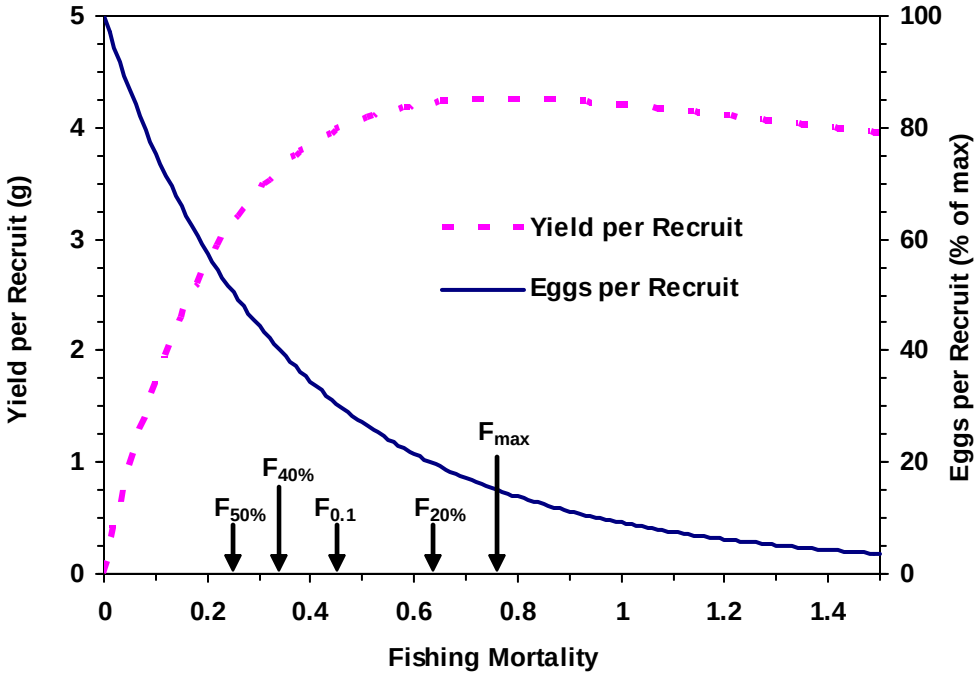


Figure 14. Yield and egg production per recruit for Gulf of Maine northern shrimp.

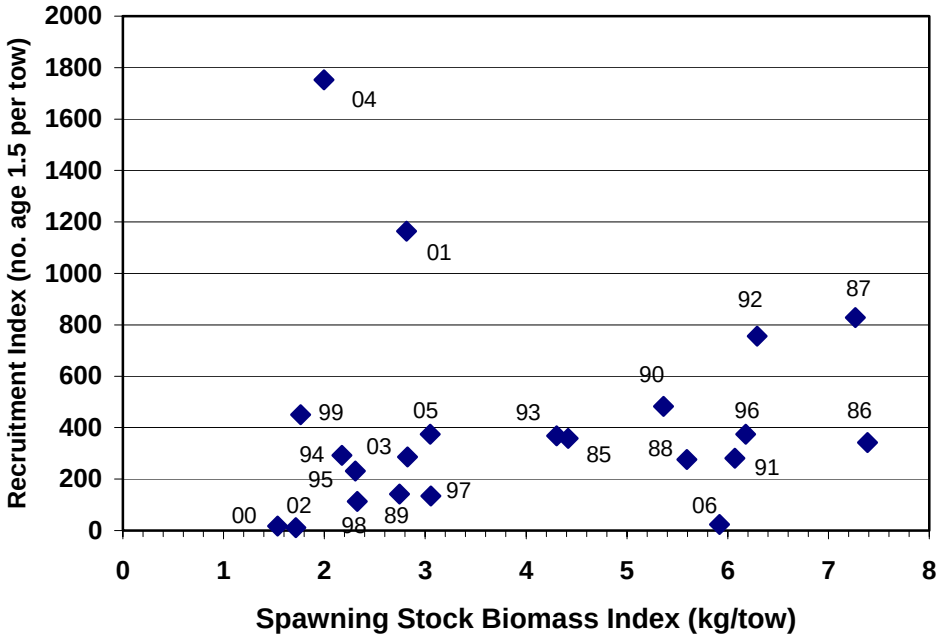
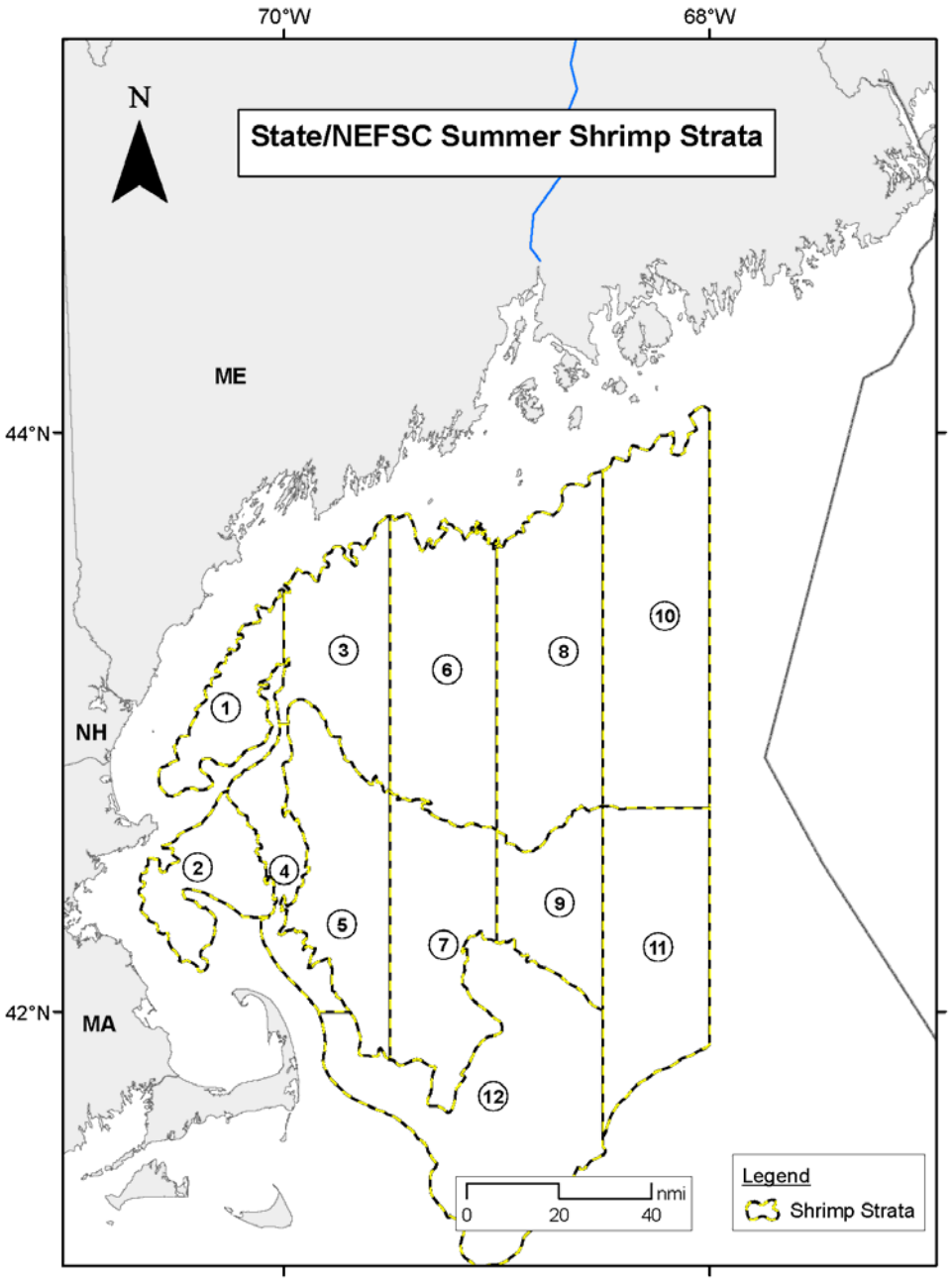


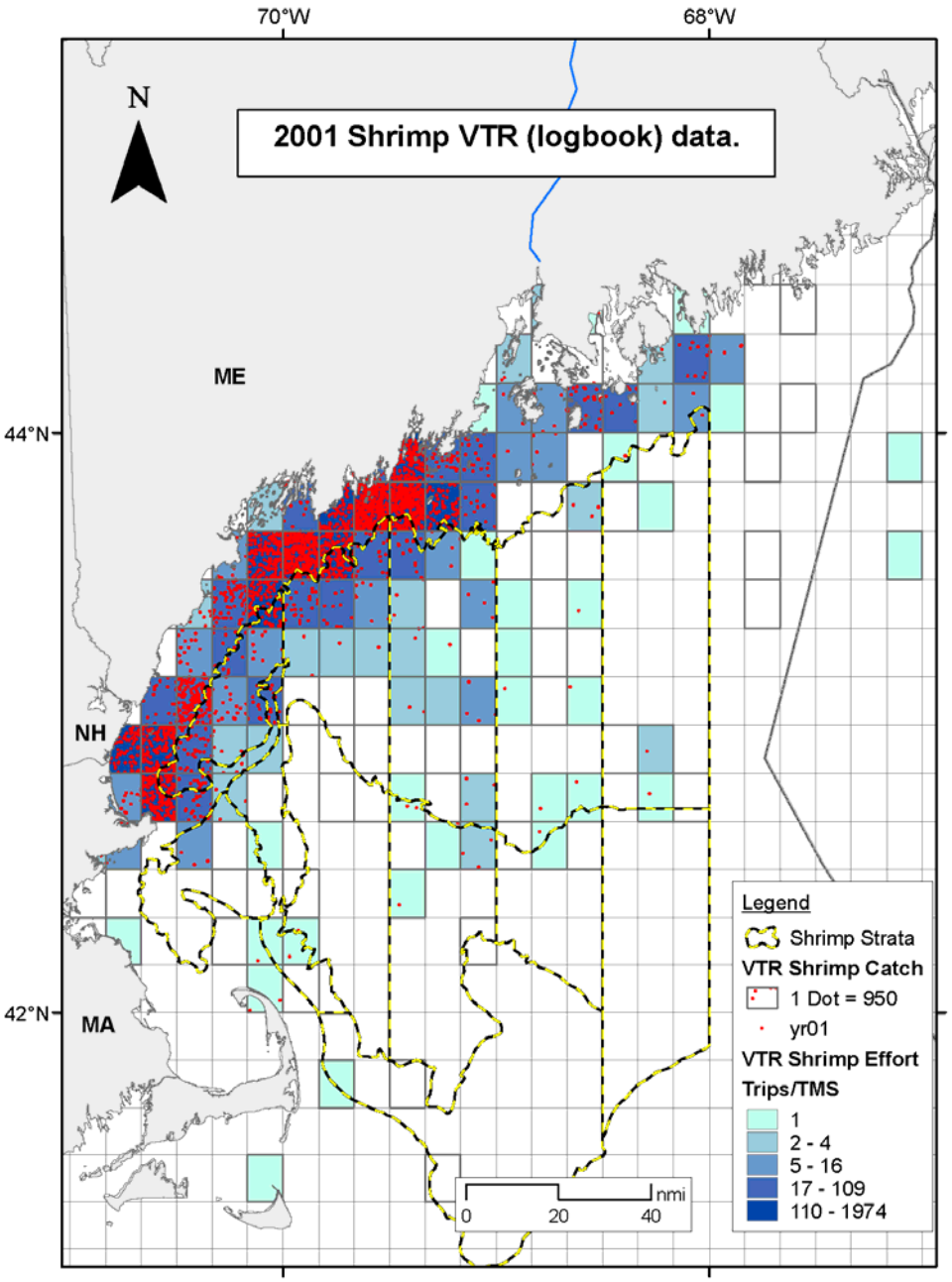
Figure 15. Relationship between summer survey index of Gulf of Maine female northern shrimp biomass the summer before spawning to age 1.5 abundance two years later. Two-digit numbers indicate the assumed age 1.5 year class.

Appendix A

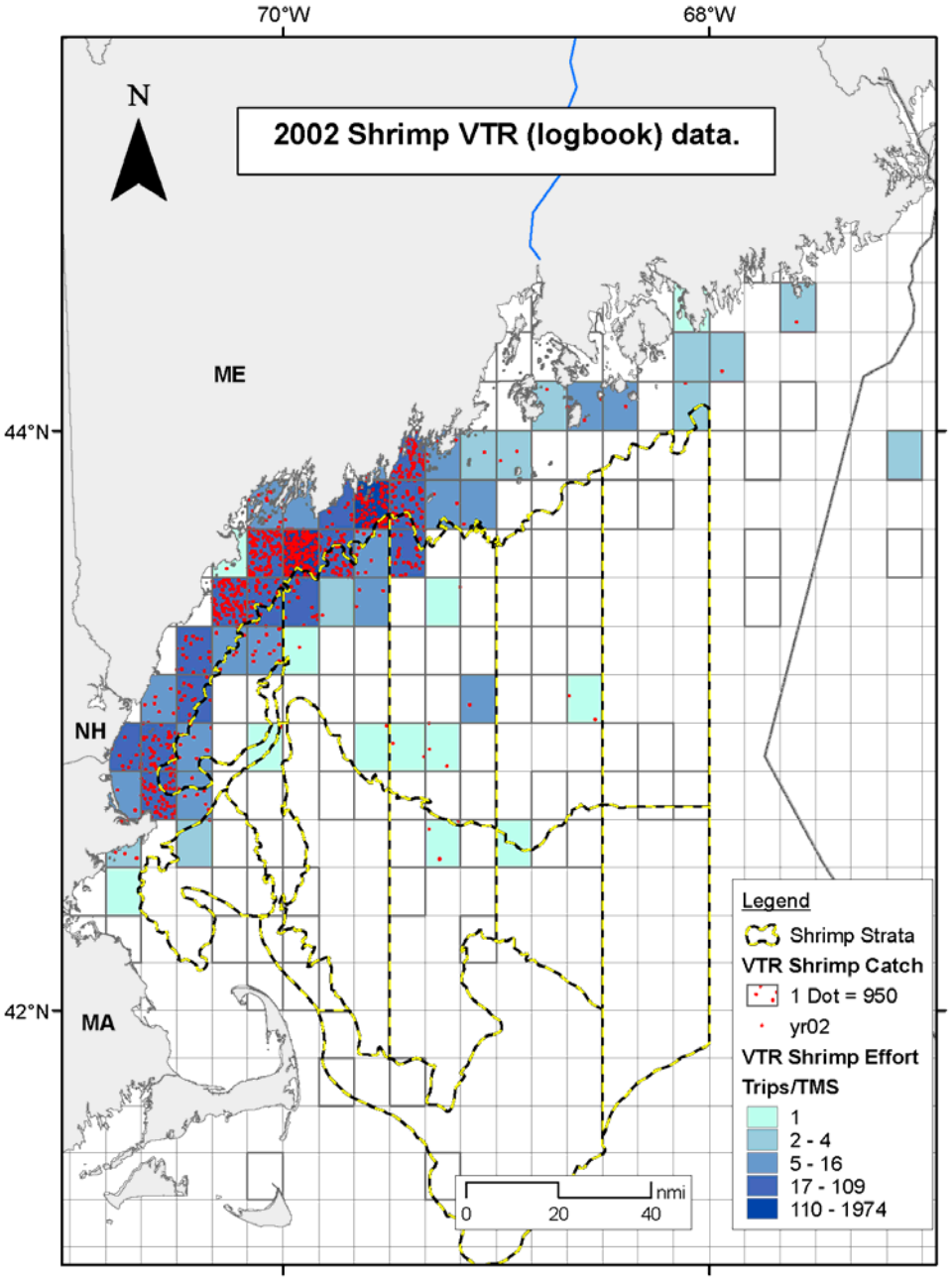
State/federal summer shrimp survey statistical strata, and pounds caught and numbers of trips during the 2001-2006 northern shrimp fishing seasons by 10-minute-square. Each red dot represents 950 lbs caught; locations of dots within squares are random. Number of trips is indicated by the blue palette for the squares. From harvester logbook (VTR) data. Does not include Maine non-federally-permitted vessel trips and catches.



Survey strata sampled during joint State/NEFSC Summer Shrimp Surveys.



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



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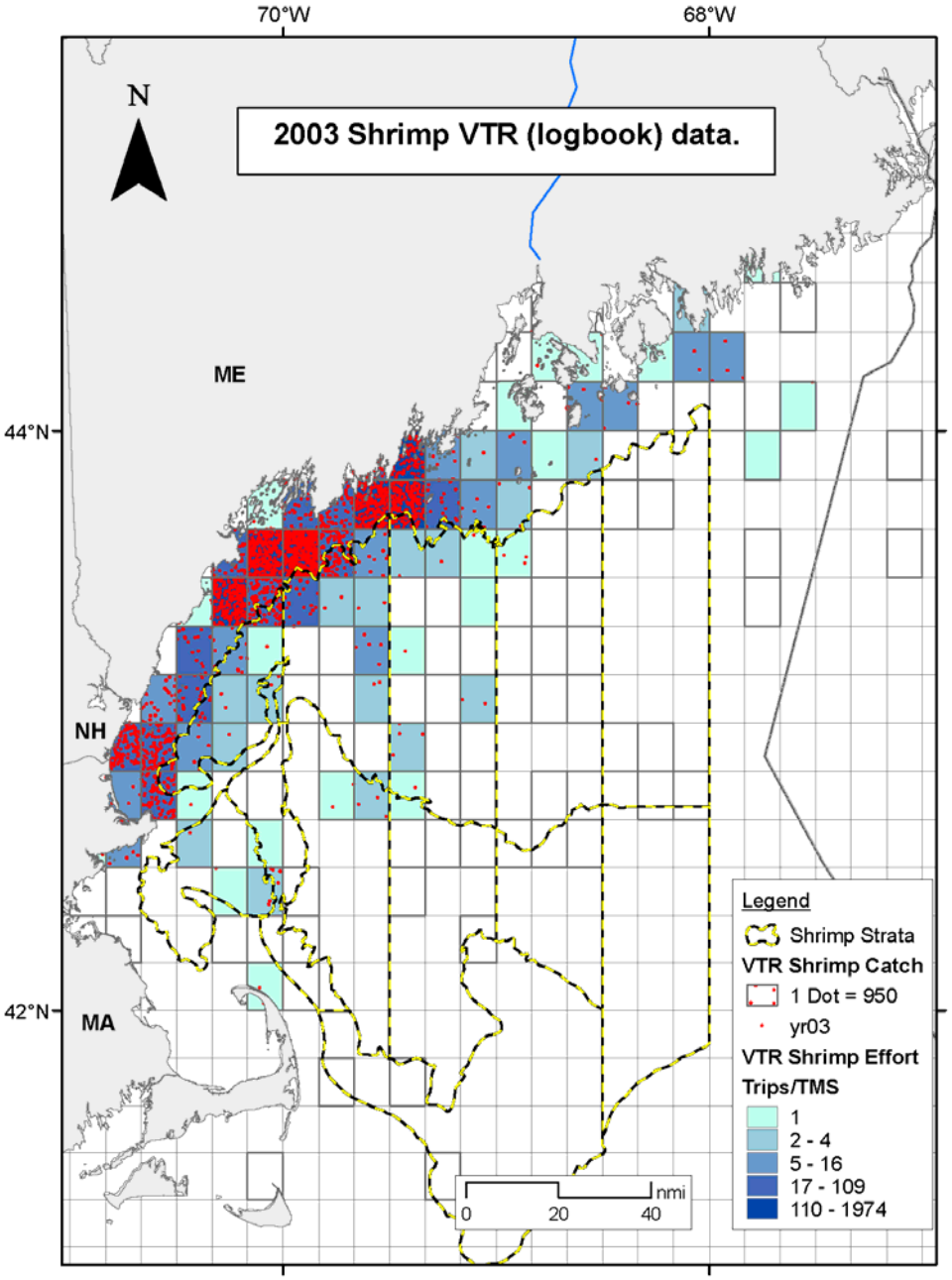

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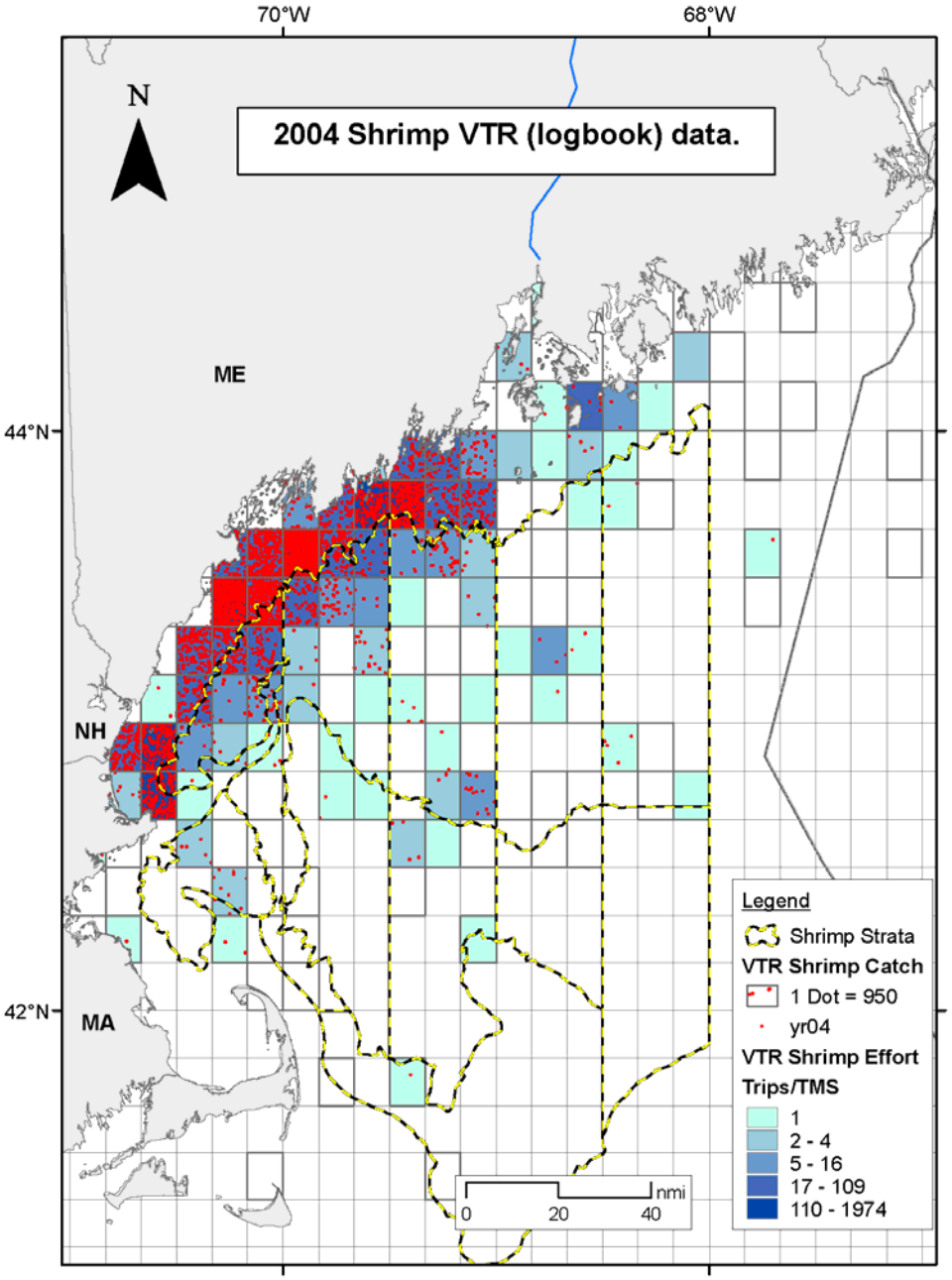

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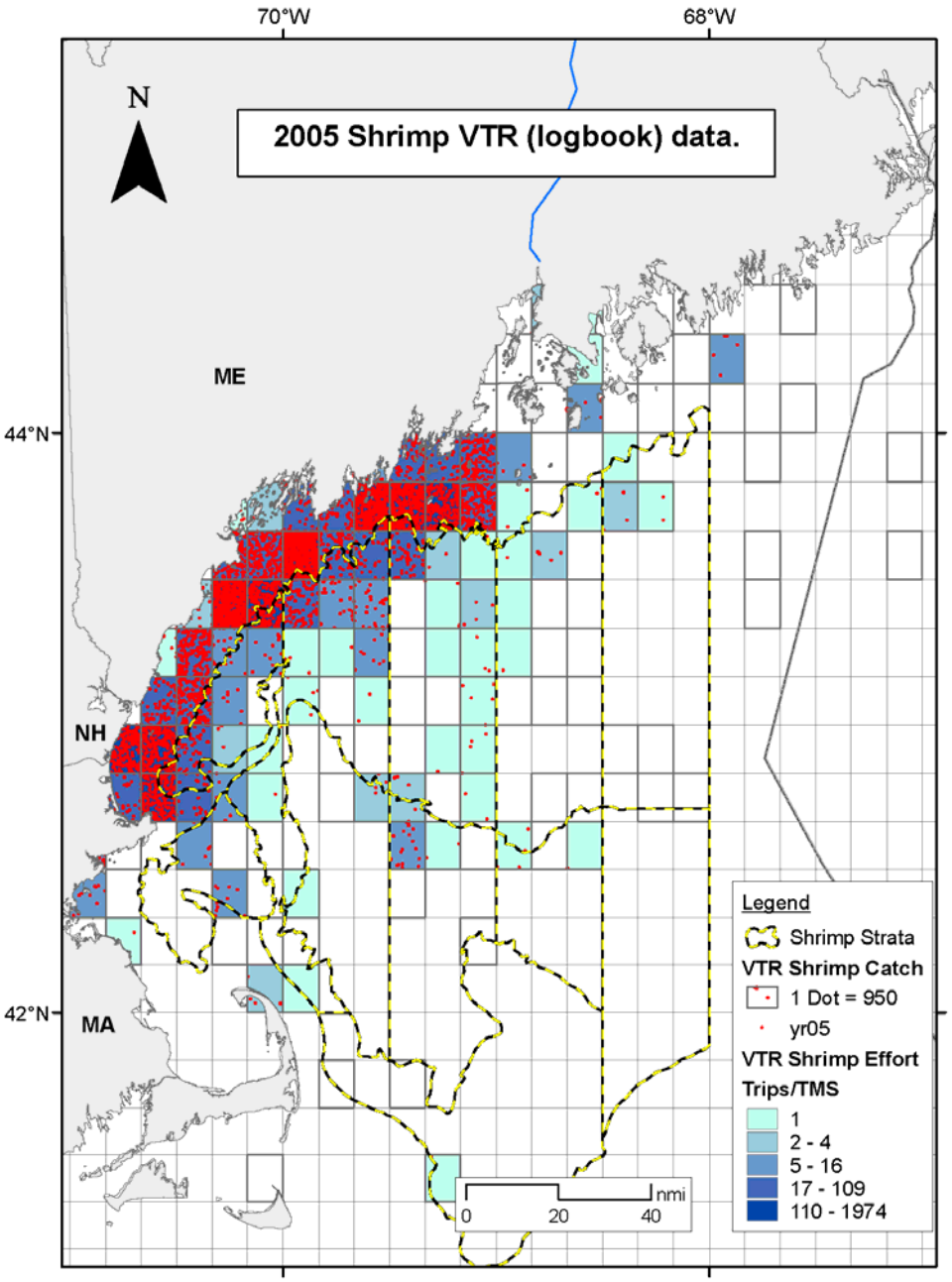

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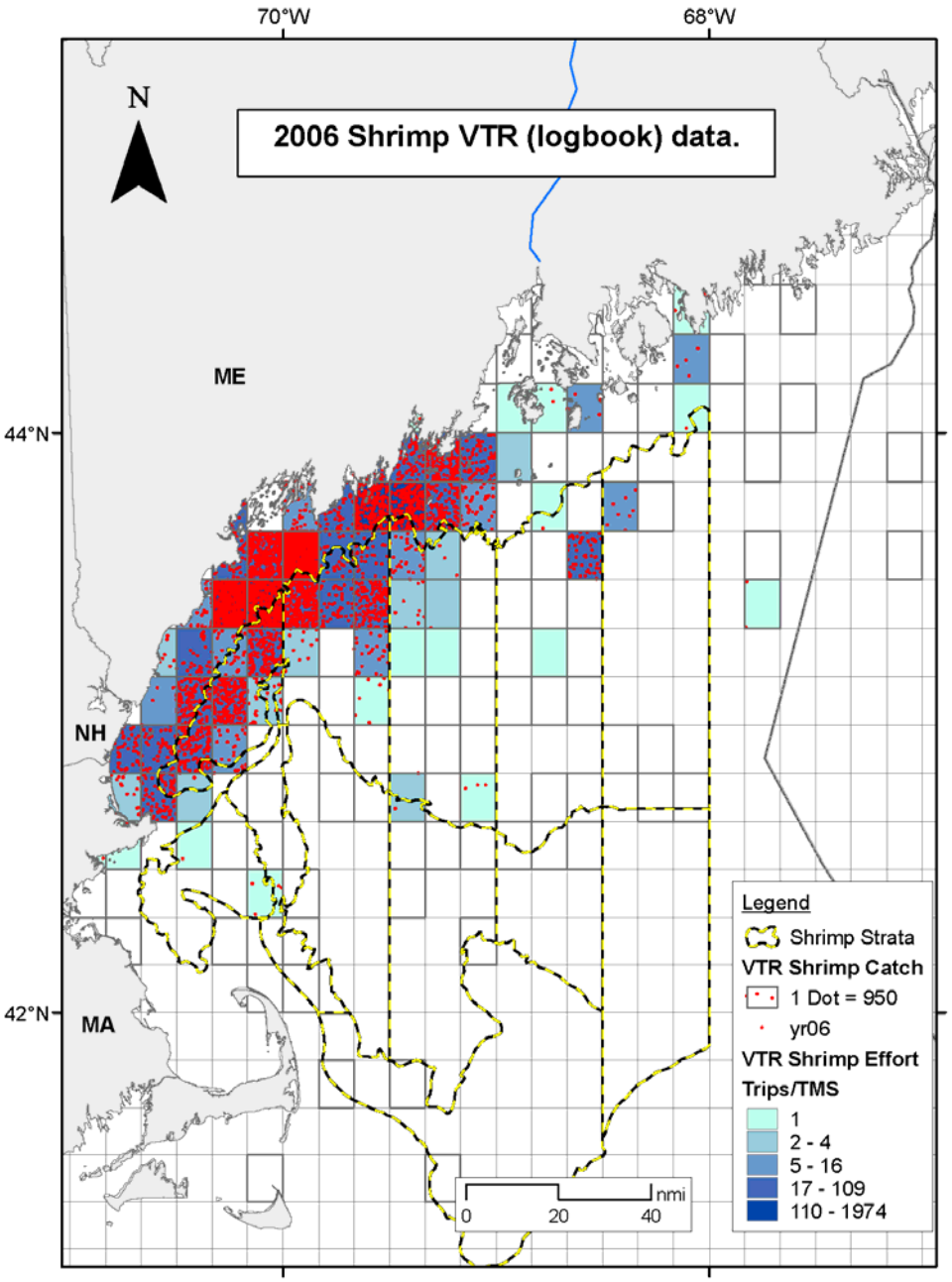

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