

A. NORTHERN SHRIMP ASSESSMENT SUMMARY FOR 2007

State of Stock: Biological reference points (BRP) for northern shrimp listed in the Atlantic State Marine Fisheries Commission's (ASMFC) Amendment 1 to the Interstate Fishery Management Plan (FMP) for Northern Shrimp, implemented in 2004, include a target/threshold annual fishing mortality rate (F) = 0.22 and threshold biomass (B) = 9,000 mt (ASMFC 2004). Based on the Collie-Sissenwine Analysis (CSA) model used in the present assessment, fishing mortality on Northern shrimp in 2006 was F = 0.03 and biomass in 2007 was 71,500 mt. Based on these reference points the Northern shrimp stock is not overfished and overfishing is not occurring (Figure A1).

Fishing mortality rate (F) has declined from a time series high of 1.07 in 1997 to a series low of F = 0.03 in 2006 (Figure A1). The 80% confidence intervals for F were (0.81 - 1.48) in 1997 and (0.02 - 0.05) in 2006.

Fully exploited biomass has been generally increasing from 4,350 mt, a series low in 2001, to 71,500 mt, a series high in 2007 (Figure A1). The 80% confidence interval for fully exploited biomass was (3,100 - 5,800 mt) in 2001 and (52,100 - 87,700 mt) in 2007. Model results show a large increase in the most recent years (2006 and 2007).

Recruit biomass ranged from 1,700 to 6,400 mt during 1985 through 2004 (Figure A2). Recruitment has shown a large increase in recent years (2006 and 2007), similar to the overall biomass, to a series high of 39,000 mt in 2007 (See Table below). The terminal estimate of recruitment should be viewed with caution because the value is well beyond previous observed values and is based in part on the 2006 Northern Shrimp Technical Committee (NSTC) Summer Shrimp survey, which had a fairly modest number of tows in 2006 as compared to historical surveys. The 80% confidence intervals for recruit biomass were (12,900 - 34,000 mt) in 2006 and (30,200 - 44,600 mt) in 2007.

Catch and Status Table (weights in '000 mt): Northern Shrimp

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Max ¹	Min ¹	Mean ¹
Commercial Landings²	4.2	1.8	2.4	1.3	0.42	1.2	1.9	2.6	1.9	-	9.2	0.42	3.52
Fishing mortality (F)	0.73	0.46	0.51	0.30	0.08	0.14	0.23	0.18	0.03	-	1.06	0.03	0.34
Biomass³	5.6	4.7	4.7	4.4	4.7	5.8	8.0	13.0	32.1	71.5	71.5	4.4	14.1
Recruits⁴	2.5	2.2	1.7	1.8	1.8	2.5	2.7	6.5	22.9	39.0	39.0	1.7	6.1

¹Over period 1985 – 2006 for commercial landings and F; over period 1985 – 2007 for stock biomass and recruits.

²Includes removals by experimental studies (2002-2006); 2005 and 2006 are preliminary.

³ Values represent the fully-exploitable stock biomass (> 22 mm CL).

⁴ Values represent shrimp biomass that will become available to the fishery in the coming fishing year.

Stock Distribution and Identification: *Pandalus borealis* is distributed throughout the North Atlantic and Arctic Oceans. In the Gulf of Maine, northern shrimp populations comprise a single stock (Clark and Anthony 1981), which is concentrated in the southwestern region of the Gulf of Maine (Haynes and Wigley 1969; Clark et al. 1999). Water temperature, salinity, depth, and substrate type are important factors governing Northern shrimp distribution in the Gulf of Maine (Haynes and Wigley 1969; Apollonio et al. 1986; Shumway et al. 1985). The Gulf marks the

southern-most extent of this species' range in the Atlantic Ocean, and seasonal water temperatures in many areas regularly exceed the upper physiological limit for northern shrimp.

Landings: A directed winter fishery in coastal waters developed in the late 1930s, which landed an annual average of 63 mt (139,000 lbs) from 1938 to 1953, but no shrimp were landed from 1954 to 1957 due to low inshore availability (Wigley 1973). The fishery resumed in 1958, and landings increased steadily to a peak of 12,824 mt (28,272,000 lbs) in 1969 as an offshore, year-round fishery expanded (Figure A3). After 1972, landings declined rapidly, and the fishery was closed in 1978. The fishery reopened in 1979 and seasonal landings increased gradually to 5,253 mt (11,581,000 lbs) by 1987 and averaged 3,300 mt (7,275,000 lbs) from 1988 to 1994. Landings peaked at 9,166 mt (20,208,000 lbs) in 1996 and declined to a low in 2002 of 424 mt (935,000 lbs). The 2002 landings were the lowest northern shrimp landings since the fishery was closed in 1978, and were the result of an extremely depressed stock biomass and a very limited season. Landings increased to 2,553 mt (5,628,000 lbs) (preliminary) in 2005. Landings for 2006 were 1,877 mt (4,138,000 lbs) (preliminary) with poor market conditions.

Discards: Sea sampling observations aboard trips using a shrimp trawl from 1989 to 1997 and 2001 to 2006 in the Gulf of Maine (NMFS statistical areas 511, 512, 513, and 514) indicate that the mean weight of shrimp discards is less than 1% of total catch for all years except 1997, when it was 1.36%. From examination of the observer database for 1989 to 2006, the only other fisheries that had trips with significant shrimp discards were the small-mesh herring and whiting fisheries. This assessment does not include commercial discards in parameter estimates.

Data and Assessment: Commercial landings by state and month have been compiled by NMFS port agents from dealer reports. These data were used for annual stock assessments until 2001, when vessel trip reports (VTRs) were found to be more complete. Landings (quantity kept, not discarded) and numbers of vessels and trips have been calculated from VTRs for use in assessments since 2001. A port sampling program has been in place since the early 1980s to characterize catch at length and developmental stage, as well as to collect effort and fishing depth and location data. A Gulf of Maine summer survey from 1967 to 1983, Northeast Fishery Science Center fall trawl surveys, and Gulf of Maine state/federal summer shrimp survey from 1983 to present are used as indices of abundance. The current NSTC Gulf of Maine summer survey provides indices of recruitment and year class strength.

Primary estimates of biomass and fishing mortality were derived from the Collie Sissenwine Analysis model (CSA) using descriptive information for the Gulf of Maine shrimp fishery (total catch, port sampling, trawl selectivity, survey catches, and life history studies). The CSA estimates of abundance, biomass and fishing mortality stock status are used to provide stock status advice. A surplus production model (ASPIC) fit to three survey indices and a catch time series dating back to 1968 is used as an alternative method of estimating stock size and F . This analysis is used to corroborate results from CSA analysis and is important to provide a better historical context of potential stock size. Natural mortality (M), has been assumed to be 0.25 in the analytical assessments for Northern shrimp, and is consistent with the biological reference points in the FMP (please refer to the special comments section for further discussion).

Biological Reference Points: Biological reference points (BRPs) defined in ASMFC's Amendment 1 to the Northern Shrimp FMP (ASMFC 2004) are $B_{\text{Threshold}} = 9,000$ mt (19.8 million lbs) and $B_{\text{Limit}} = 6,000$ mt (13.2 million lbs), and $F_{\text{Target/Threshold}} = 0.22$ and $F_{\text{Limit}} = 0.60$.

These are the first reference points adopted for assessing the northern shrimp stock and are used in the current assessment.

A total biomass target is not defined in Amendment 1. The biomass limit is set at 2,000 mt higher than the lowest observed biomass of northern shrimp. The target/threshold of $F = 0.22$ is based on a level of the fishing mortality rate in the mid-1980s through mid-1990s when biomass and landings were “stable”. The limit of $F = 0.6$ is based on the limit that was exceeded in the early to mid-1970s when the stock collapsed. The F target/threshold of 0.22 and the F limit of 0.6 correspond to Spawning Potential Ratios (SPR) of F50% and F20% respectively.

BRPs values presented in this assessment are based on biomass and fishing mortality estimates that assume M is 0.25. Given recent evidence (see Special Comments) that natural mortality is likely to be greater than 0.25, BRPs will need to be revised in the future to be consistent with the level of M used for calculating fishing mortality and biomass.

Fishing Mortality: Annual estimates of fishing mortality rate (F) ranged from 0.19 to 0.32 (average = 0.22, 19% exploitation) for the 1985 to 1994 fishing seasons, peaked at 1.06 (57% exploitation) in the 1997 season and decreased to 0.30 (22% exploitation) in the 2001 season (Figure A1). In 2002, F dropped to 0.08 (7% exploitation), due in part to a short season and poor stock conditions. Continued poor stock conditions (in terms of exploitable shrimp) resulted in F rising to 0.23 (18% exploitation) in 2004. Exceptional recruitment of the 2004 year class combined with very poor market conditions led to F dropping to 0.03 (3% exploitation) in 2006, the lowest in the time series. Recent patterns in F reflect a decline in nominal fishing effort.

Recruitment: Recruit biomass was relatively flat from 1985 through 2005, ranging from 1,700 to 6,500 mt (Figure A2). Poor recruitment was observed for the 1983, 1989, 1997, 1998, 2000, and 2002 year classes (Figure A4). Recruitment failure of the 2002 year class continues to be a concern, as is the mediocre first appearance of the 2005 year class.

Recruitment has shown a large increase in the last two years reaching a series high of 39,000 mt in 2007 due to the unprecedented 2004 year class. The terminal estimate of recruitment should be viewed with caution (see State of Stock).

Stock Biomass: Between 1985 and 1993, total stock biomass estimates averaged about 14,000 mt, with a peak at 16,000 mt before the 1991 season, and a decrease to a time series low of 4,400 mt in 2001. Total stock biomass has since increased to 71,500 mt in 2007 (32,100 mt in 2006) (Figure A1). While the absolute values of these estimates have associated larger uncertainty, the trend is reasonable because both fall and summer survey indices have been increasing since 2002.

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the Gulf of Maine summer survey from 1984-2006 are given in Figure A5. The \log_e transformed mean weight per tow averaged 15.8 kg/tow between 1984 and 1990. Beginning in 1991 this index began to decline and averaged 10.2 kg/tow between 1991 and 1996. The index then declined further, averaging 6.1 kg/tow from 1997 to 2001, and reaching a time series low of 4.3 kg/tow in 2001. In 2002 the index increased 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 new time series highs in both 2005 (23.3 kg/tow) and 2006 (66.0 kg/tow). The total mean number per tow had similar trends over the time series.

Special Comments: Extremely high estimates of northern shrimp biomass in 2007 are the result of unprecedented high survey indices in 2006. While all evidence suggests that the stock size of

shrimp is quite large at present time, recent estimates of biomass should be viewed with caution because of the increased uncertainty of the estimates associated with the low number of tows made during the 2006 NTSC Summer Shrimp Survey. That said, there are no apparent patterns in the distribution of the 2006 survey that shed serious doubt on the validity of the 2006 index. The high abundance currently observed might not continue because the biomass estimate of the 2004 year class may not be as large in subsequent years, which would imply fewer shrimp available for the fishery.

Analyses presented in the assessment document suggest the assumed value of natural mortality rate ($M = 0.25$) is too low. The value of $M = 0.6$ is more reasonable; however, further analysis to determine the most appropriate value of M should be conducted in the next assessment. BRPs will need to be revised to reflect any changes made in M .

In the future, BRPs should be described using text as well as with specific values. For example, instead of only stating that the $F_{\text{Threshold}}$ is 0.22, it should also be described as the CSA estimate of the mean for the stable period, 1985 – 1994.

Management advice based on $M = 0.25$ does not pose a large risk to the stock given the current extremely high biomass and the nature of the current BRP's.

Sources of Information:

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- Atlantic States Marine Fisheries Commission (ASMFC). 2004. Amendment 1 to the interstate fishery management plan for northern shrimp. ASMFC Fish. Man. Rpt. No. 42, 69p, <http://www.asmfmc.org/northernShrimp.htm>
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- Clark, S.H. and V.C. Anthony. 1981. An assessment of the Gulf of Maine northern shrimp resource. In: T. Frady, ed., Proceedings of the International Pandalid Shrimp Symposium. University of Alaska Sea Grant Report 81-3, Fairbanks. p. 207-224.
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- Haynes, E.A. and R.L. Wigley. 1969. Biology of the northern shrimp, *Pandalus borealis*, in the Gulf of Maine. Trans. Am. Fish. Soc. 98: 60-76.
- Northeast Fishery Science Center (NEFSC). 2003. Report of the 36th Northeast Regional Stock Assessment Workshop (36th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. US Dept. Commerce NEFSC Ref. Doc 03-06, Woods Hole, MA., 453p. <http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0306/>.
- Shumway, S.E., H.C. Perkins, D.F. Schick, and A.P. Stickney. 1985. Synopsis of biological data on the pink shrimp *Pandalus borealis* Krøyer, 1838. NOAA Technical Report NMFS 30, 57 p.
- Wigley, R.L. 1973. Fishery for northern shrimp, *Pandalus borealis*, in the Gulf of Maine. Mar. Fish. Rev. 35(3-4): 9-14.

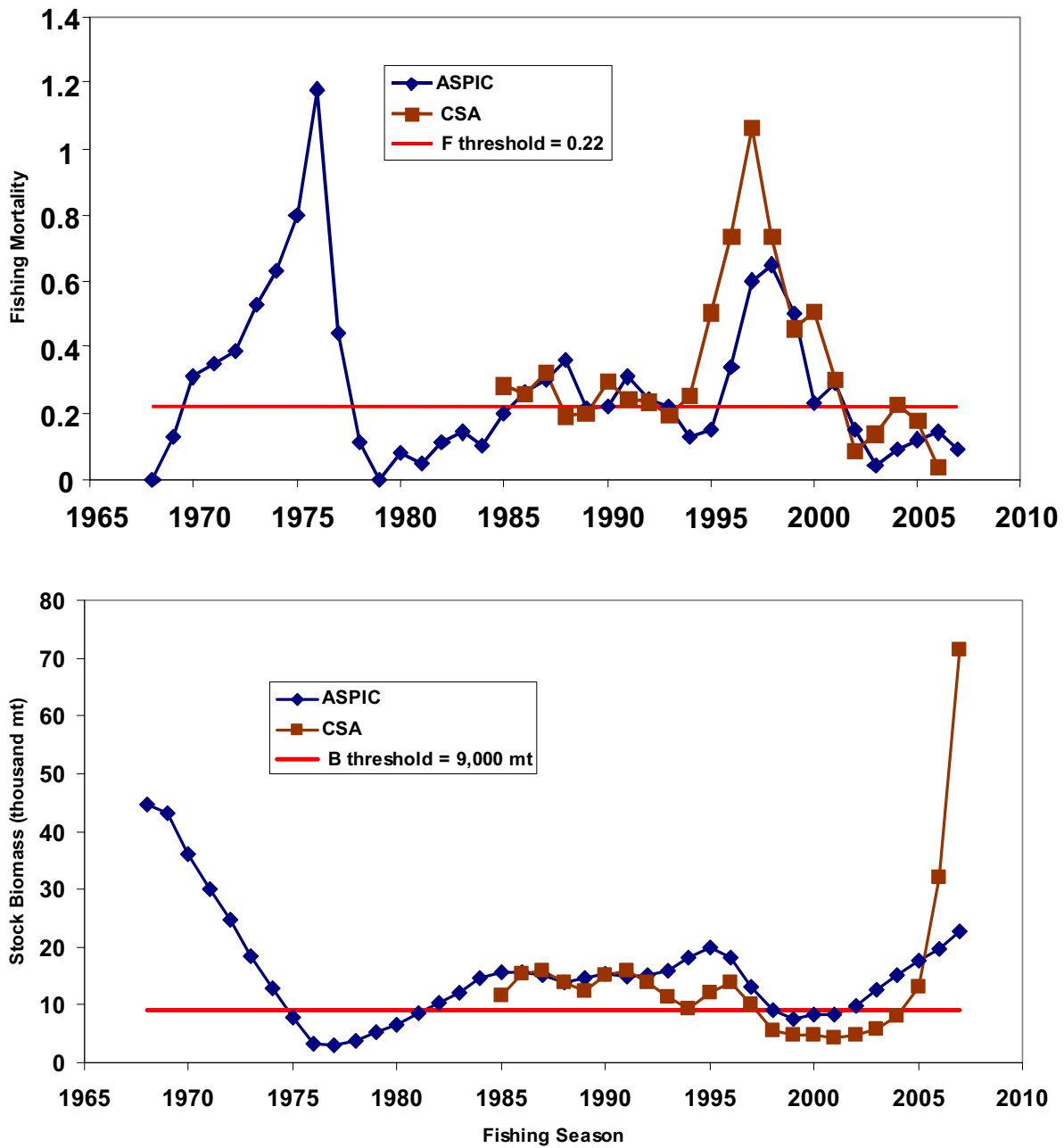


Figure A1. Annual fishing mortality rate (above) and stock biomass (below) for Gulf of Maine northern shrimp from CSA (primary assessment model) and ASPIC (used for historical context and corroboration) modeling. Thresholds are also indicated.

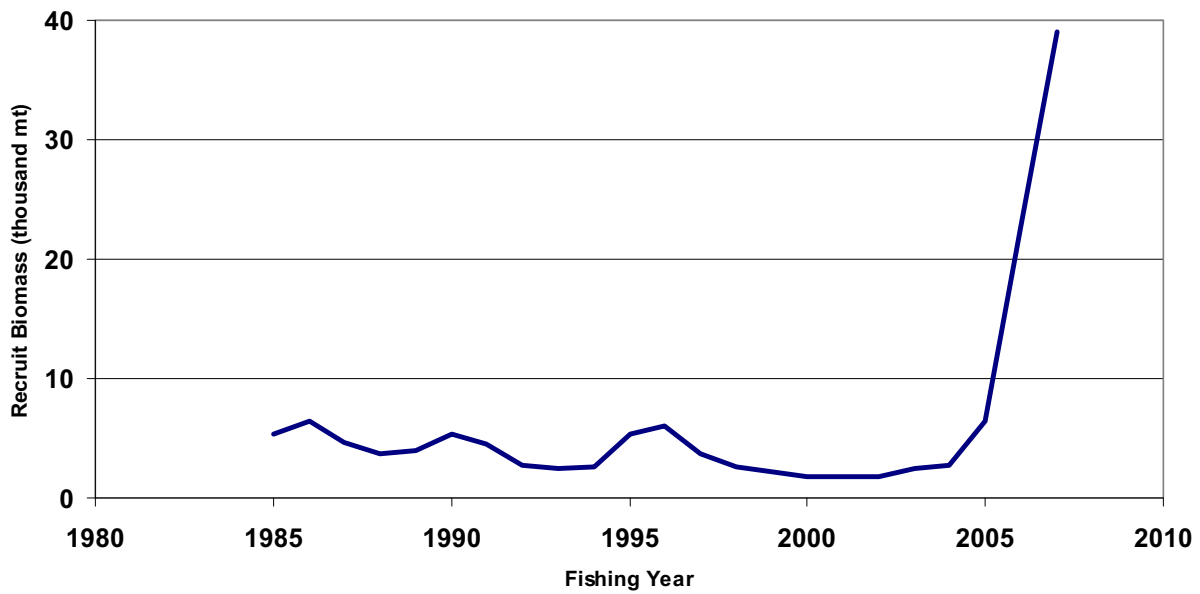


Figure A2. Annual recruit biomass (those shrimp that will recruit to the fishery in the coming fishing year) for Gulf of Maine northern shrimp from CSA analyses.

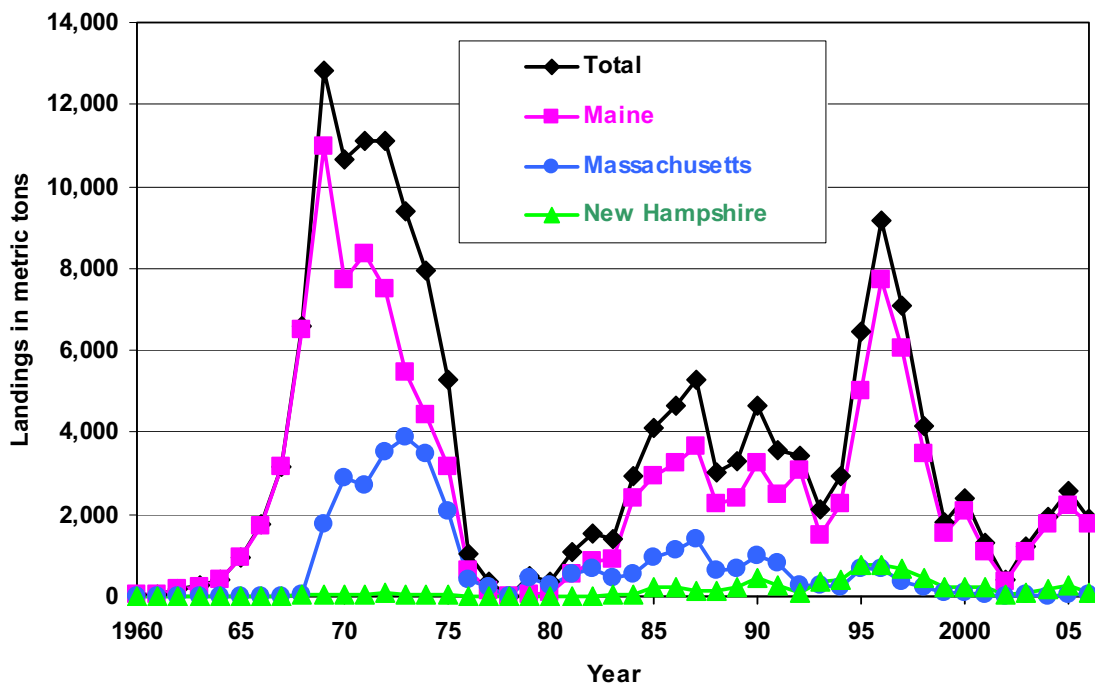


Figure A3. Gulf of Maine northern shrimp landings by year and state. (1 metric ton = 2,205 lbs)

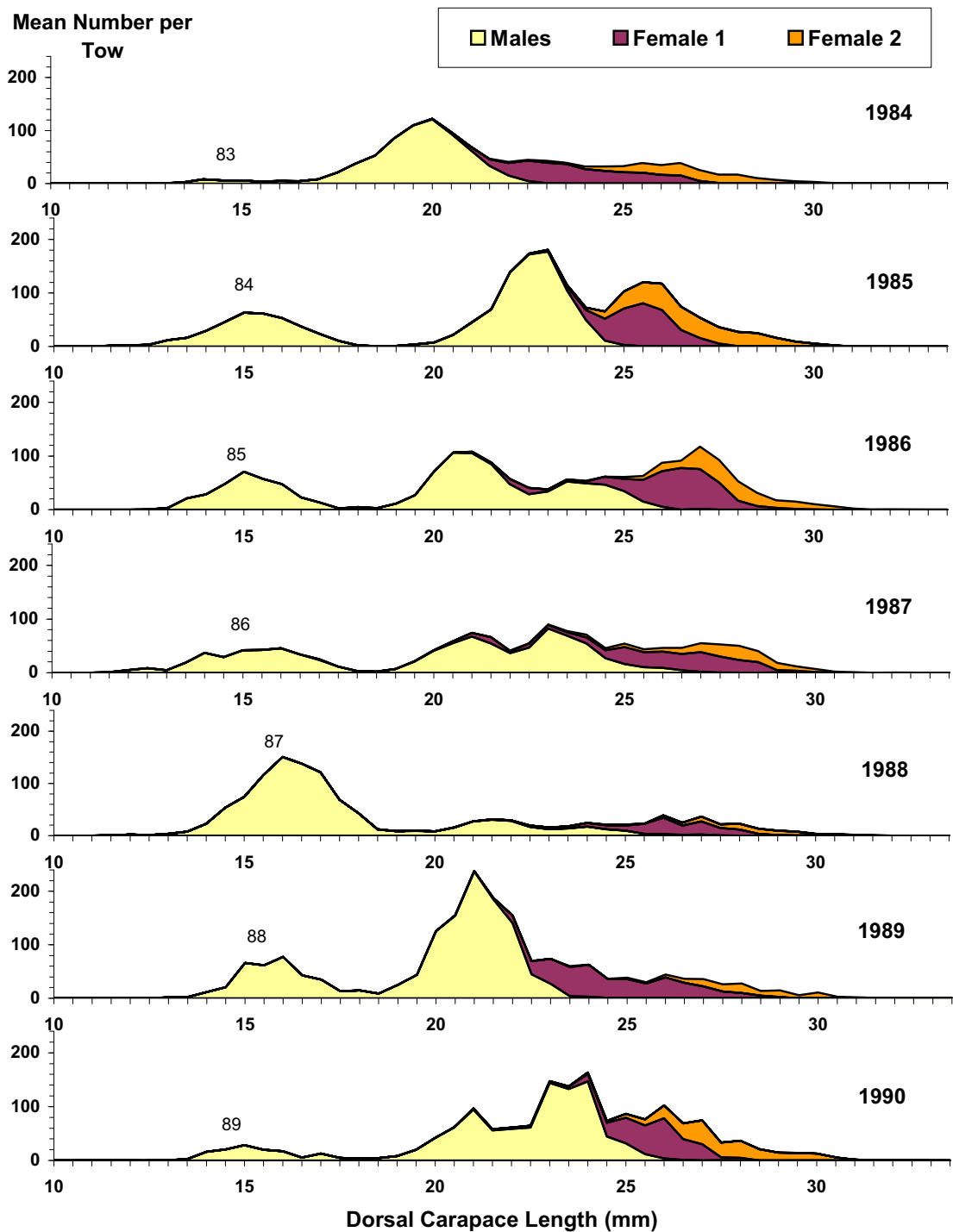


Figure A4. Mean number of shrimp per survey tow by survey year, shrimp length, and development stage for Gulf of Maine northern shrimp. Data are from the State/federal NSTC summer survey. Two-digit years indicate the year class at assumed age 1.5 years.

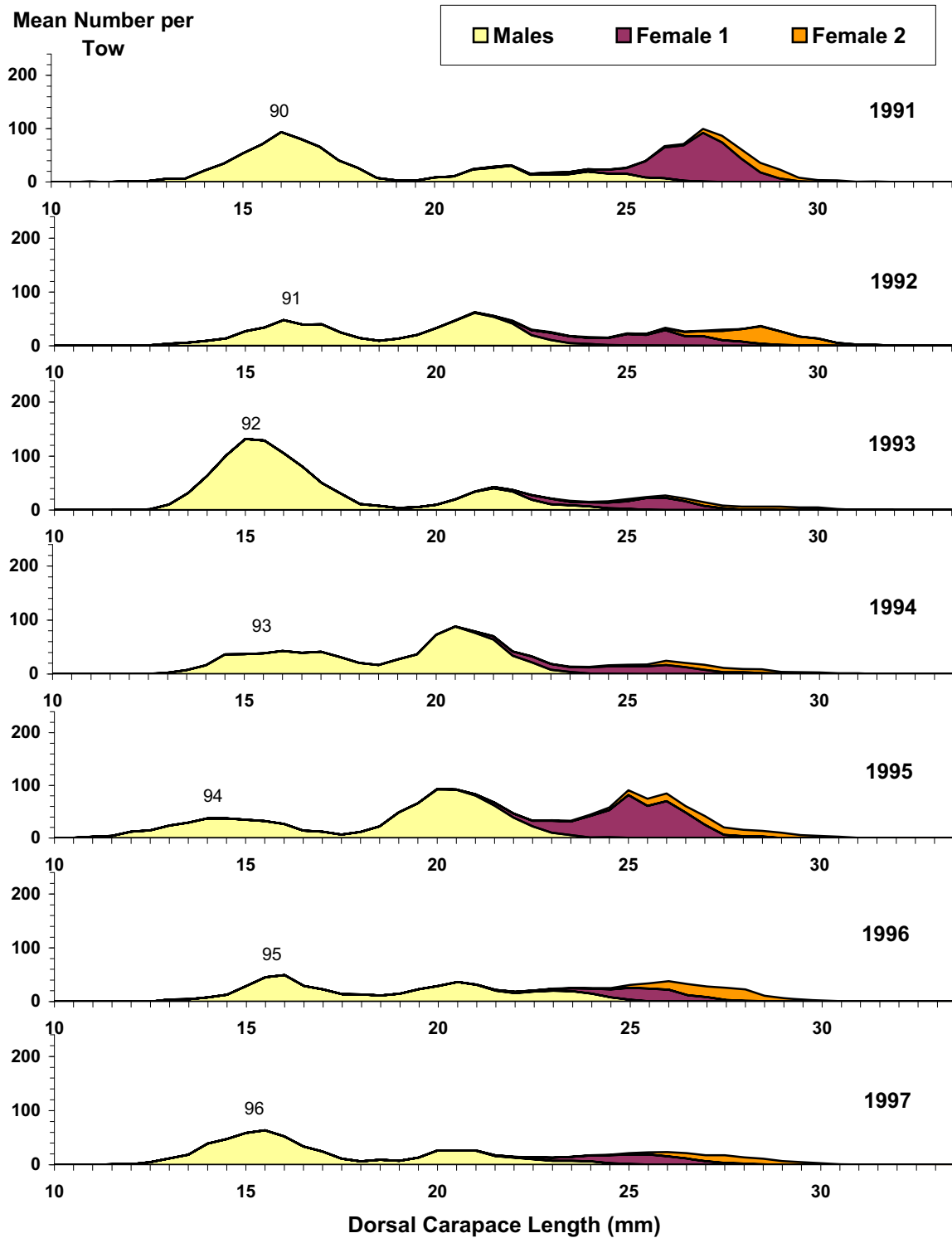


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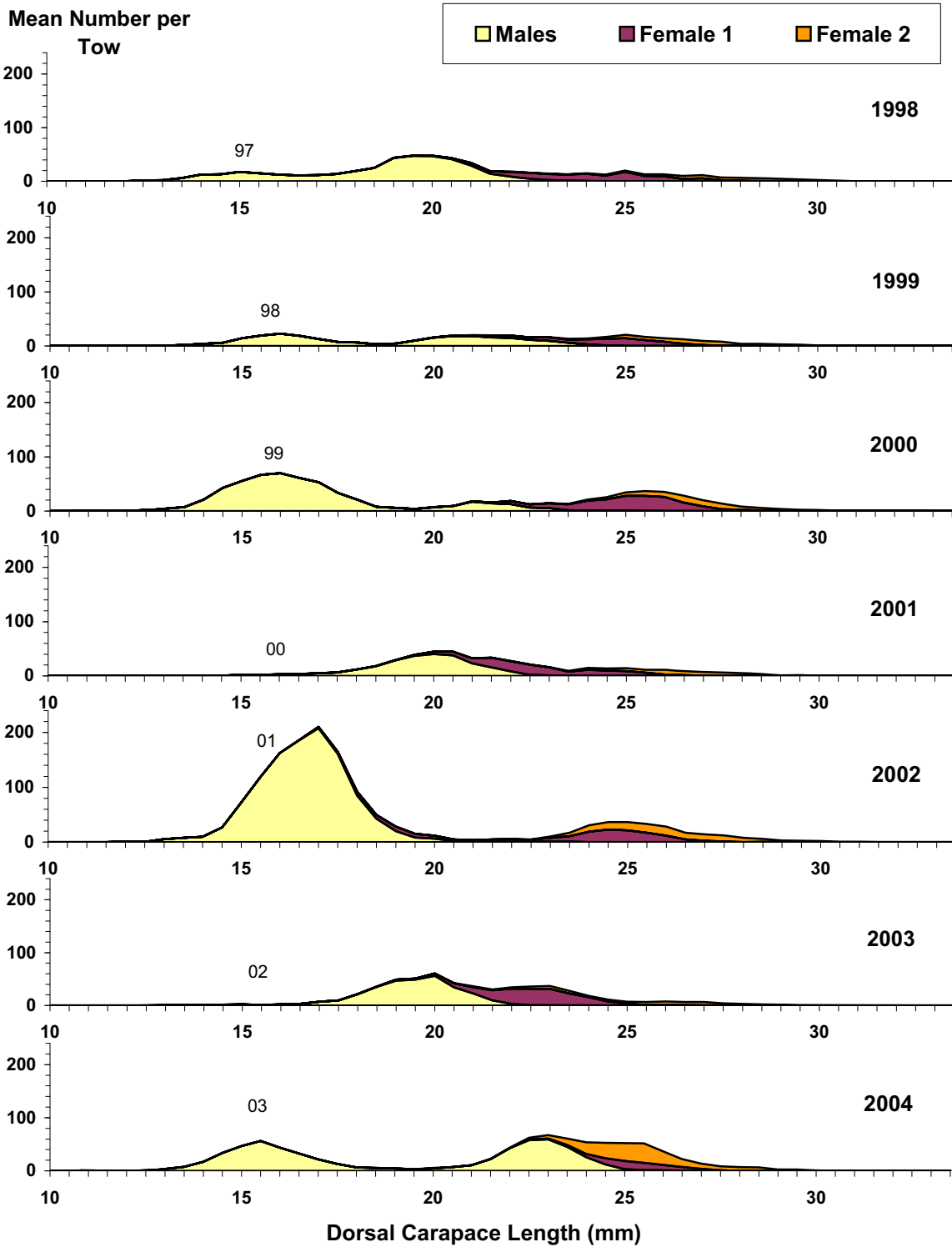


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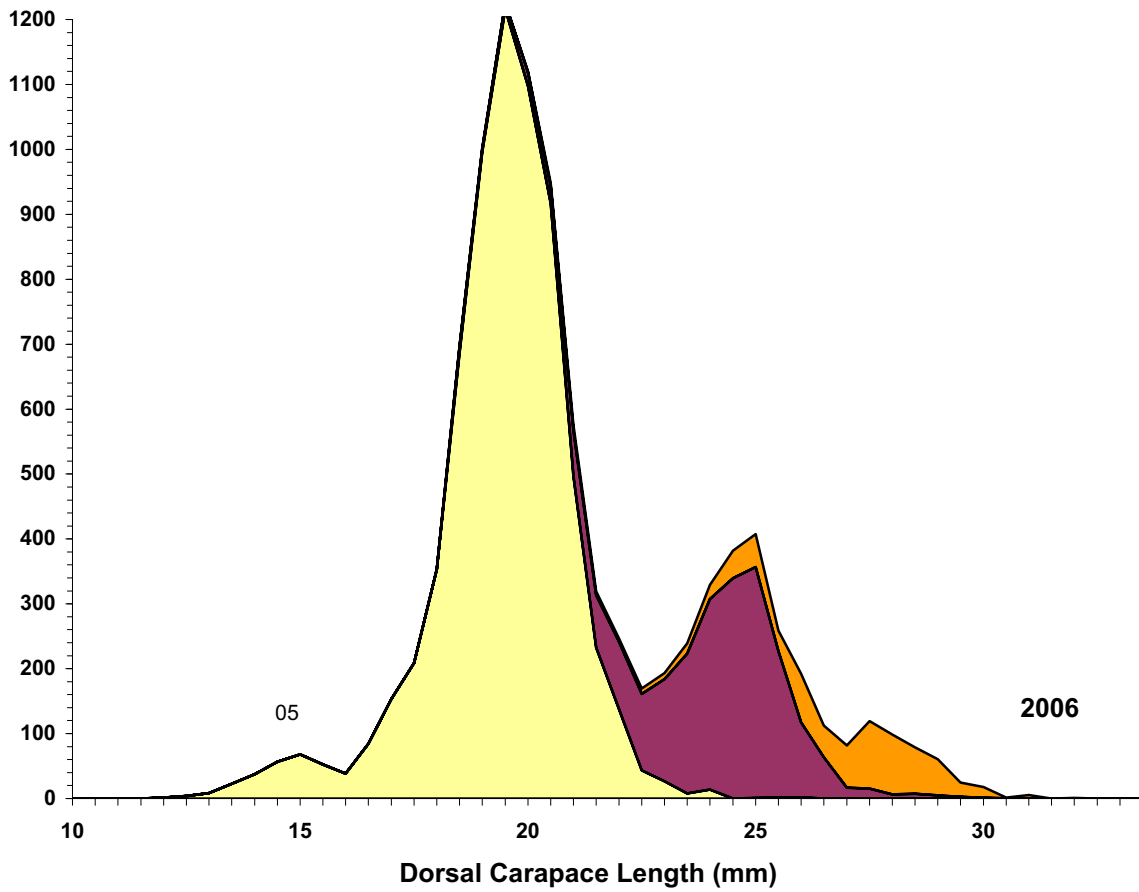
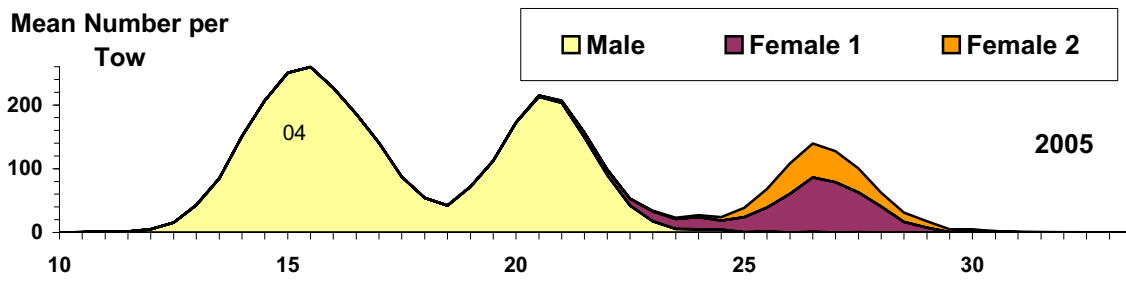


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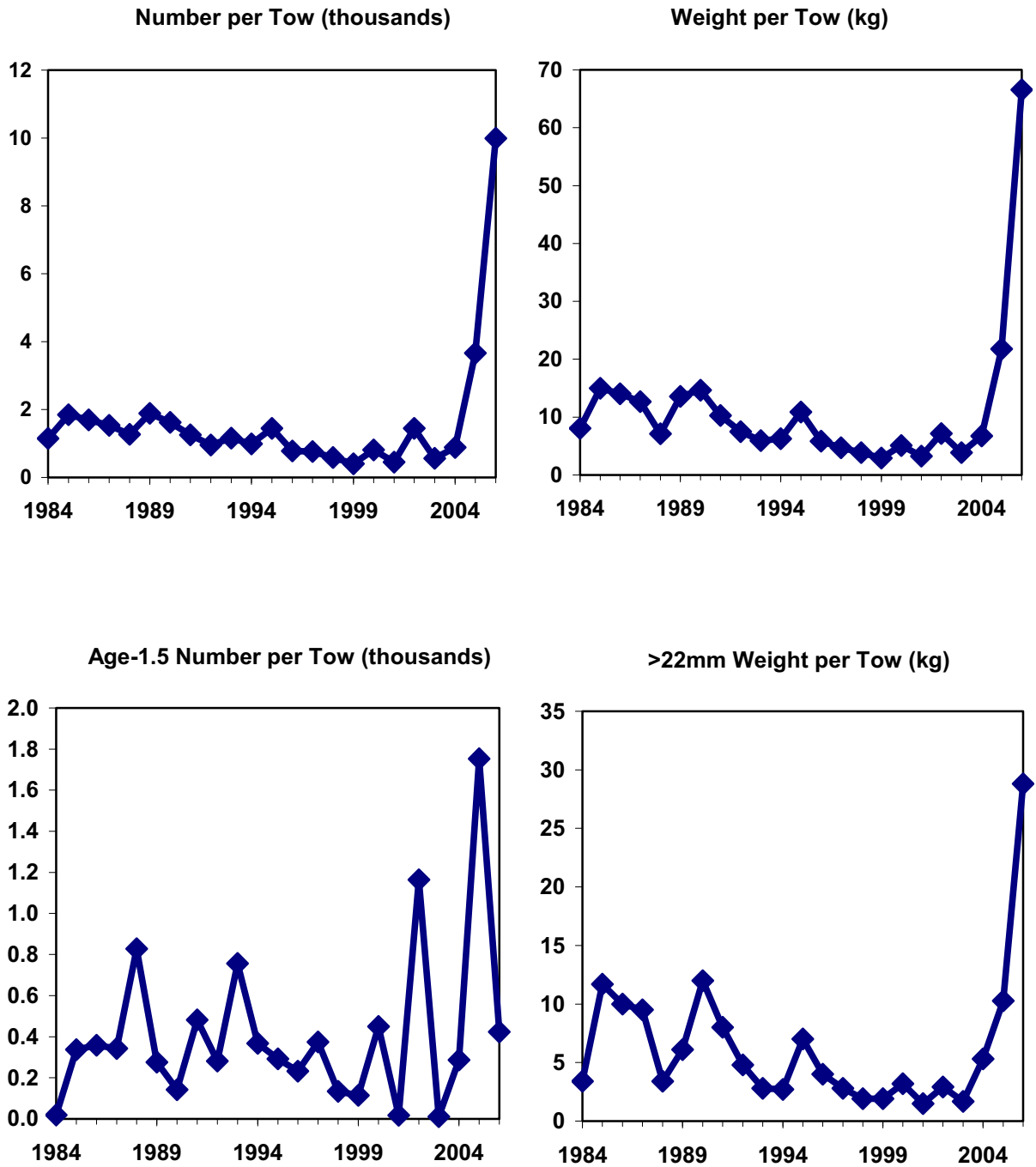


Figure A5. State/federal summer survey indices of abundance and biomass of Gulf of Maine northern shrimp. (1 kg = 2.2 lbs)