C. Northern Shrimp

State of Stock: Currently there are no quantitative status determination criteria adopted by ASMFC. The stock is below the average level of biomass, and current fishing mortality rate (F) is below all standard F reference points. For the period 1985–1995, F ranged from 0.15 to 0.57. Between 1996 and 1998, F ranged from 0.70 to 1.18, the highest values seen since the stock collapsed in the late 1970s. From 1999 to 2002, it declined from 0.42 to 0.06. For the period 1985-1995 exploitable biomass ranged from 9,200 to 22,500 mt and averaged 16,800 mt. From 1998 to 2002, biomass ranged from 5,700 to 9,200 mt, averaged 6,600 mt, and is currently about 9,200 mt. The 2001 year class is among the largest on record while the 2000 year class was among the smallest on record.

Management Advice: Fishing mortality should be kept low to minimize the risk of further decline in stock size, and to protect the 1999 and 2001 year classes. Managers should establish appropriate reference points (targets, thresholds, and limits) and consider control rules that account for the unique life history characteristics of northern shrimp.

Forecast: No projections were performed in this assessment.

Catch and Status Table: Northern Shrimp
(landings in mt, abundance in millions)

	Fishing Year Estimates[2]											Summary[1]		
Year:	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Min	Max	Mean
Landings	2.1	2.9	6.5	9.2	7.1	4.2	1.8	2.4	1.3	0.4[3]		0.4	9.2	3.9
F[4]	0.20	0.28	0.57	0.76	1.18	0.70	0.42	0.48	0.24	0.06		0.06	1.18	0.37
Exploitation	16%	22%	39%	48%	63%	45%	30%	34%	19%	5%		5%	25%	63%
Recruits[5]	512	711	975	883	534	510	408	303	445	358	1001	303	1313	762
Full Recruits[5]	881	713	809	1003	764	425	391	393	409	448	634	391	1519	898
Biomass[5]	12.4	9.2	12.4	15.5	11.0	6.7	5.8	5.7	6.2	6.1	9.2	5.7	22.5	13.2

[1]Over the 1985-2003 time period
[2] Fishing year (August of previous calendar year to July of current calendar year)
[3] 2002 landings estimate is preliminary
[4]Average F for all sizes
[5]At the start of the fishing year

Stock Distribution and Identification: Northern shrimp (or pink shrimp), *Pandalus borealis*, are distributed discontinuously throughout boreal waters of the North Atlantic, North Pacific, and Arctic Oceans. In the Gulf of Maine, they are considered to constitute a single unit stock. They inhabit soft muddy bottom at depths of 10-300 m, most commonly in the cold water of the southwest Gulf of Maine.

Catches: Annual commercial landings averaged 63 mt from 1938 to 1953, and no shrimp were landed from 1954 to 1957 (Figure C1). The fishery resumed in 1958 and landings increased to peak at 12,100 mt during the 1969 season. After 1972, landings declined rapidly, and the fishery was closed in 1978. The fishery reopened in 1979 and landings increased gradually to 5,300 mt by 1987, and averaged 3,300 mt from 1988 to 1994. Landings increased to 9,200 mt in 1996, a value exceeded only by the five years of landings prior to the late 1970s stock collapse. Landings declined from 1996 to 2002 to a low of 400 mt. Sea sampling observations indicate that discards have been negligible, constituting <1% of the total catch. Therefore, discard estimates were not included in the present assessment.

Data and Assessment: Total landings and indices of abundance from the summer shrimp survey were analyzed with a Collie-Sissenwine (CSA) model to estimate abundance and mortality rates for the period 1984-2002. CSA results were corroborated by a biomass dynamics model based on 1968-2002 landings, the biomass indices from the Maine summer survey (1968-83), the NEFSC fall survey (1968-2001), and the summer shrimp survey (1984-2002). Fishing mortality rates were computed using a harvest-ratio method (Collie and Kruse, 1998).

Biological Reference Points: Overfishing criteria are not currently defined in the management plan. Several analyses were considered as potential methods for developing reference points (Figure C4). Yield-per-recruit analysis indicates that $F_{max} = 0.77$ and $F_{0.1} = 0.46$. Eggs-per-recruit analysis indicates that $F_{50\%} = 0.25$, $F_{40\%}=0.34$, $F_{30\%}=0.45$, and $F_{20\%} = 0.63$. Biomass dynamics analysis (ASPIC) suggests that $F_{MSY} = 0.17$.

Fishing Mortality: Annual estimates of F averaged 0.25 (19% exploitation) from 1985 to 1995, and averaged 0.88 (52% exploitation) from 1996 to 1998 (Figure C1). Since then, F has averaged 0.30 (22% exploitation), with a value of 0.06 in 2002. The bootstrapped estimates of 2002 fishing mortality indicated an 80% probability that F was between 0.045 and 0.074 (Figure C3).

Recruitment: Four strong year classes have dominated recruitment from 1984 to 2002, the most recent being that of 2001, among the largest on record, but not yet fully recruited to the fishery. The 2001 cohort follows the five poorest years of recruitment in the time series (1997-2001).

Stock Biomass: Estimated exploitable biomass varied between 5,000 and 22,500 mt from 1985 to 2002, with a peak in 1987 (Figure C2). These fluctuations are largely caused by the passage of the strong 1982, 1987, and 1992 year classes. The estimates suggest a generally decreasing trend over the time series to a low of 5,700 mt in 1999. The advent of the 2001 year class contributed to an increase in biomass to 9,200 mt, still less than the time-series average (13,200 mt). Results of biomass dynamics analyses indicate that biomass levels were much higher (45,000 mt) in the 1960s.

Special Comments: The current assessment estimates F based on the ratio of catch to population size at the beginning of the fishing season, slightly different from the method previously used.

Catch data are currently based exclusively on vessel trip reports. Reporting deadlines (currently end of calendar year) are inadequate under this system. A substantially earlier deadline is necessary to be able to employ accurate catch data in annual assessments.

Survival of young northern shrimp is generally lower when spring surface temperature is higher (Richards *et al*. 1992). The sensitivity of recruitment to environmental variability and the level of spawning biomass should be explicitly considered in developing management strategies.

Northern shrimp are protandric hermaphrodites, and usually mature first as males and then change to females. During the last two summer surveys female shrimp were observed at progressively smaller sizes. In 2002 the smallest females were smaller than in any previous surveys. The presence of primary females may be a response to low population densities.

Sources of Information: Report of the 36th Stock Assessment Workshop (36th SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments, NEFSC Ref. Doc 03-xx; Assessment Report for Gulf of Maine Northern Shrimp - 2002, ASMFC Northern Shrimp Technical Committee 2002, R. Glenn, M. Hunter, J. Idoine, C. McBane, M. Lewis; Draft Amendment 1 to the Interstate Fishery Management Plan for Northern Shrimp; ASMFC Northern shrimp Plan Development Team; Collie, J.S. and G.H. Kruse. 1998. Estimating king crab (*Paralithodes camtschaticus*) abundance from commercial catch and research survey data. In: Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. Edited by G.S. Jamieson and A. Campbell. Canadian Special Publication on Fisheries and Aquatic Sciences 125. pp. 73-83; Richards, A., M. Fogarty, S. Clark, D. Schick, P. Diodati, and B. O'Gorman. 1996. Relative influence of reproductive capacity and temperature on recruitment of *Pandalus borealis* in the Gulf of Maine. ICES C.M. K:13.

Figure C1. Trends in Landings and Fishing Mortality

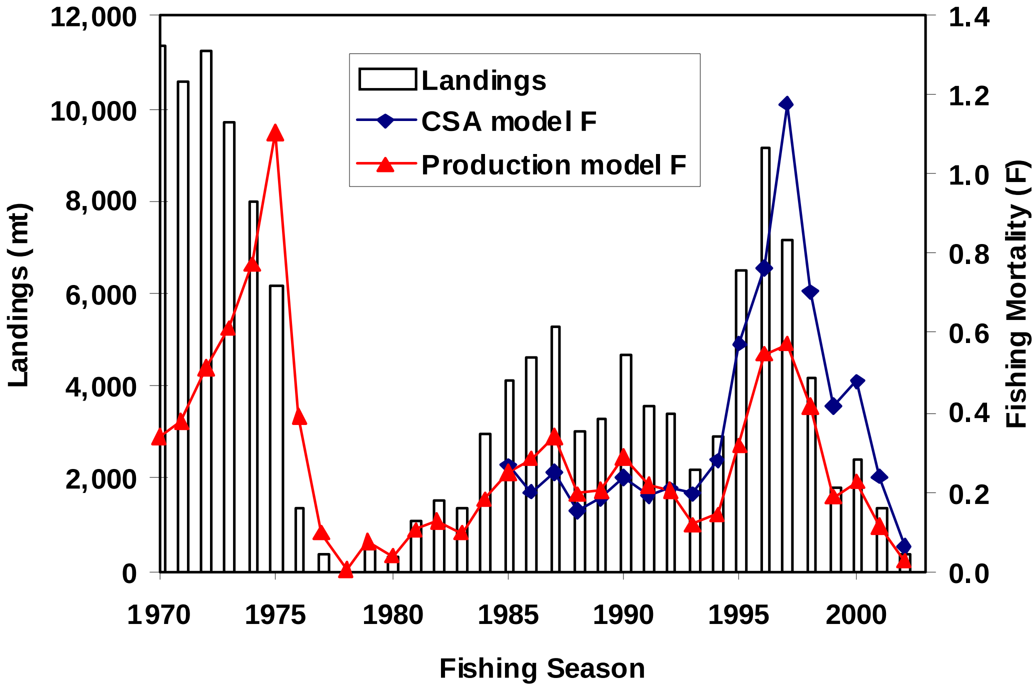

Figure C2. Trends in Abundance and Exploitable Biomass

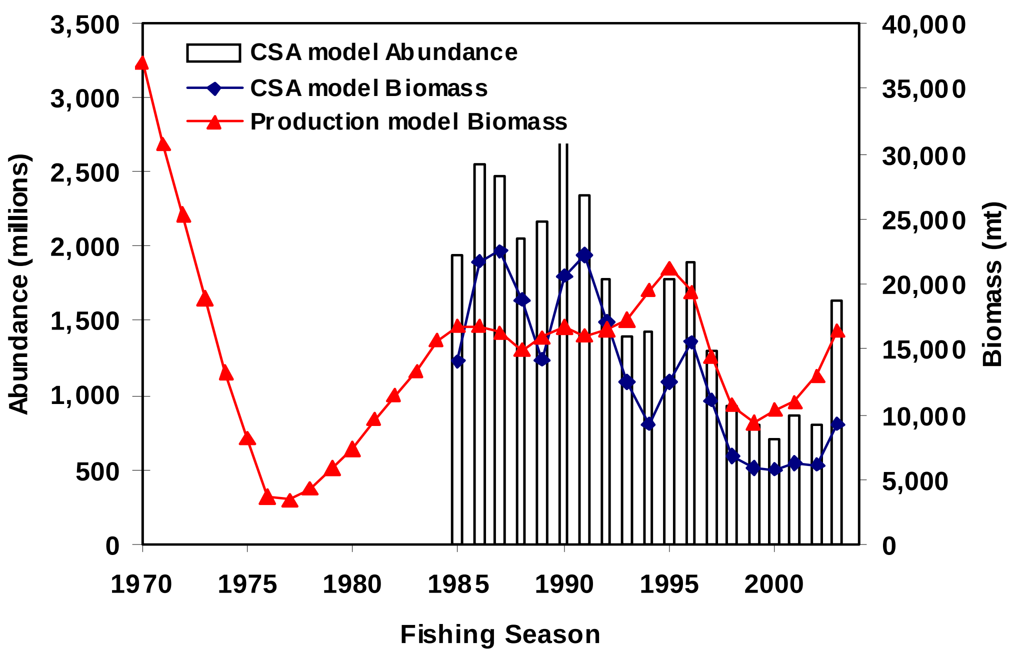

Figure C3. Precision of the 2002 Fishing Mortality Estimate

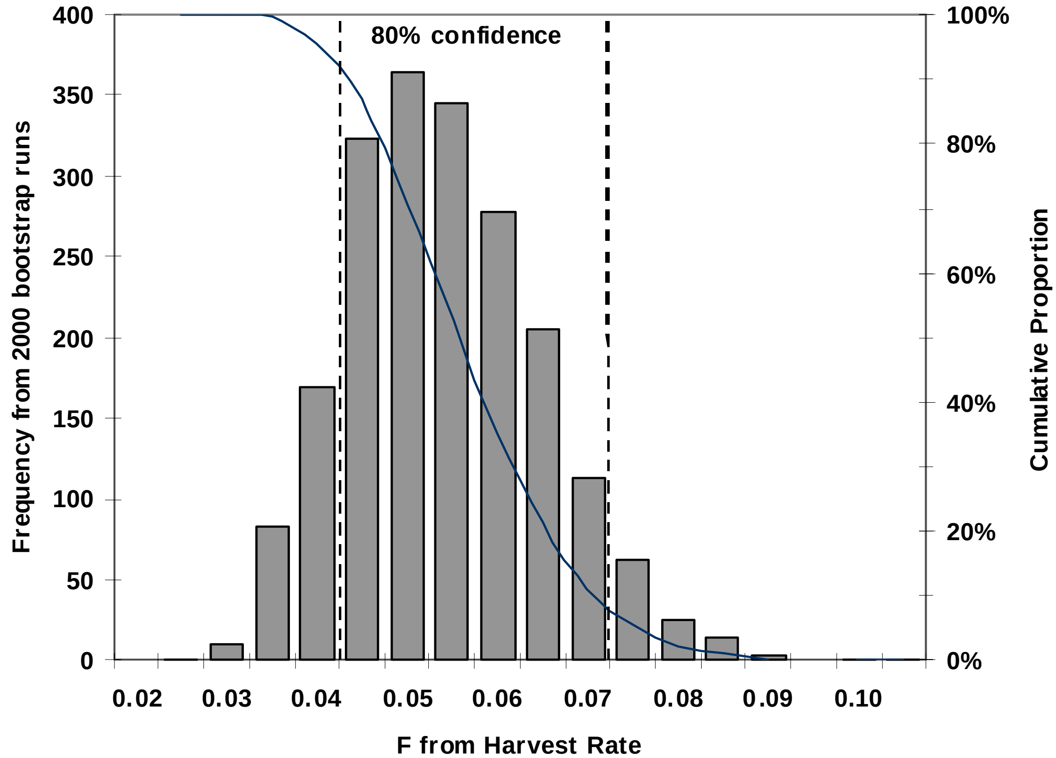

Figure C4. Yield and Egg Production per Recruit

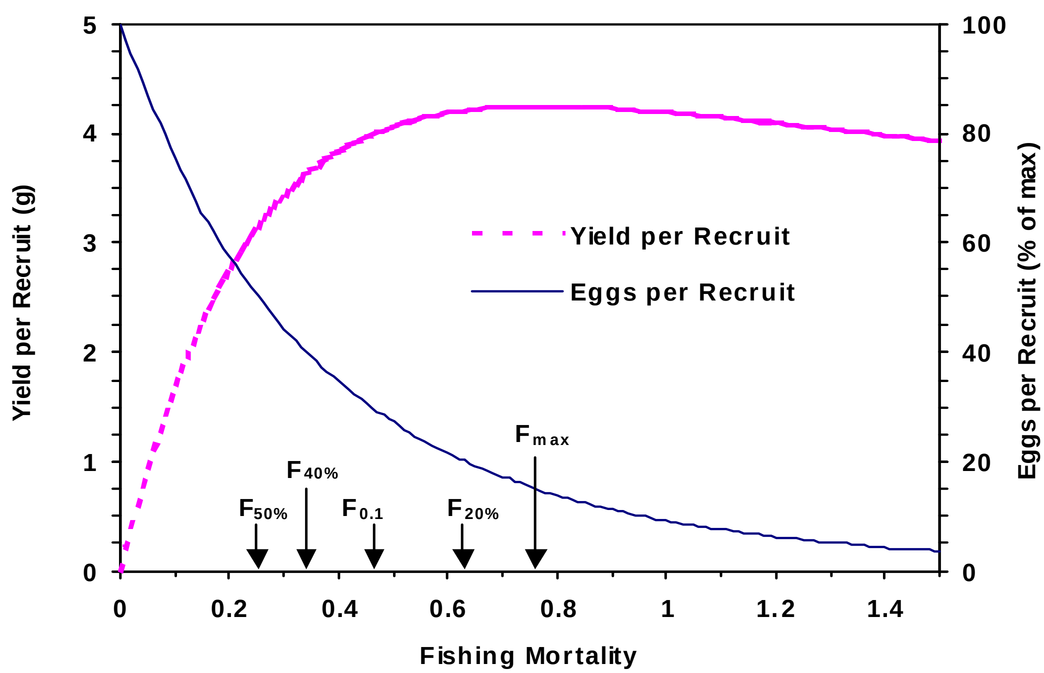

Figure C5. Relationship between summer survey index of Gulf of Maine female shrimp biomass the summer before spawning to age 1.5 abundance two years later.