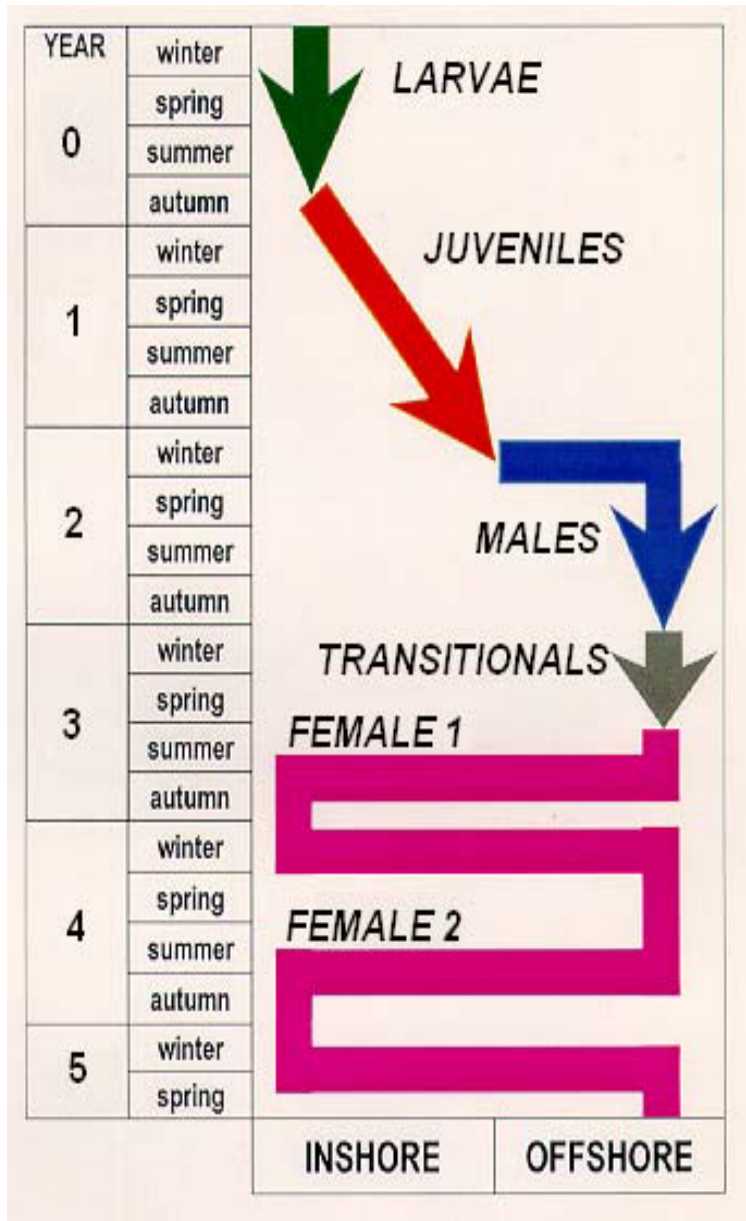# NORTHERN SHRIMP FIGURES

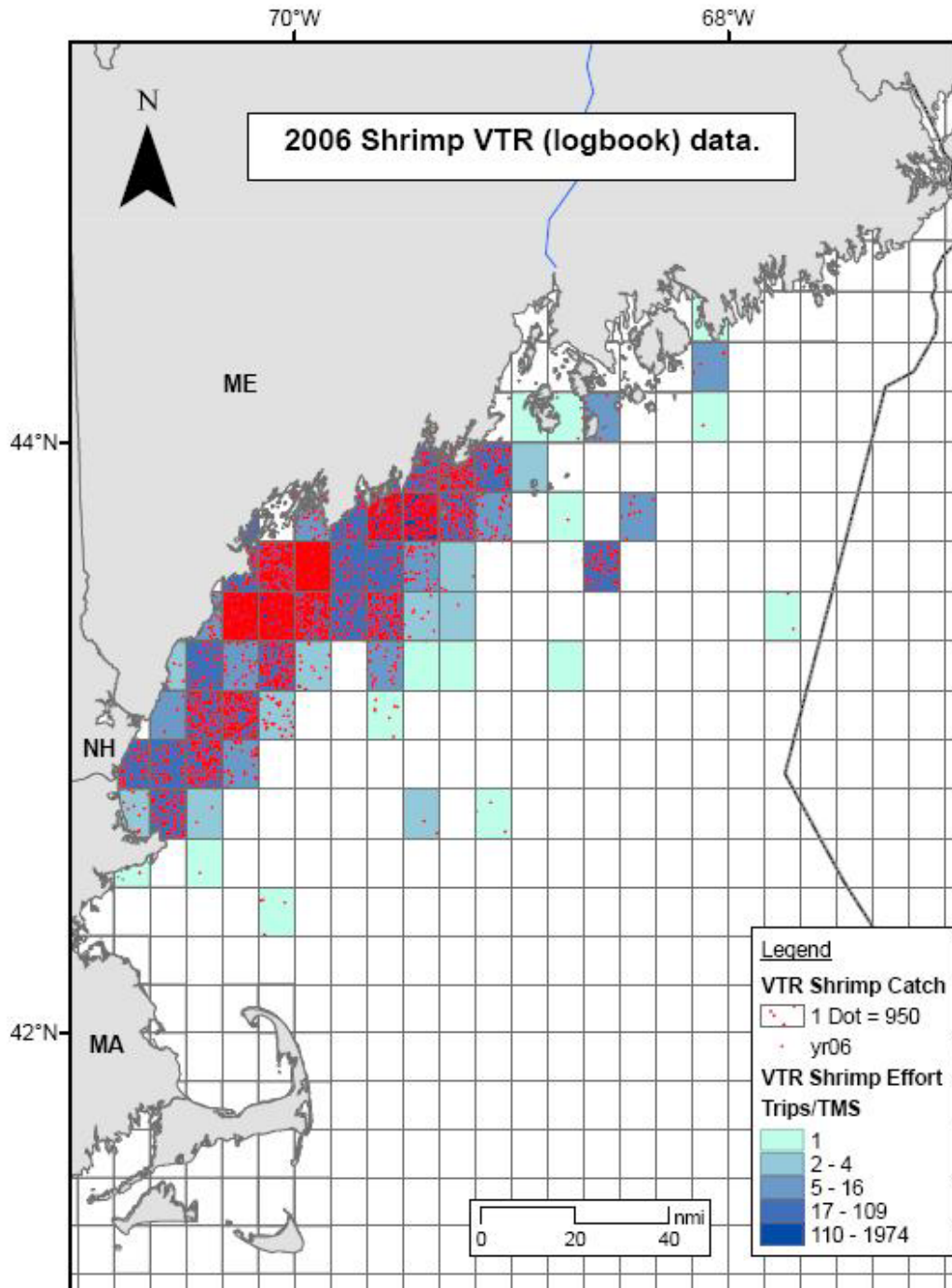Figure A4-1. Diagram of Gulf of Maine northern shrimp life history

Figure A4-2. Northern shrimp catches and effort in the Gulf of Maine from VTRs (preliminary data). Does not include some non-federally permitted Maine boat trips. Dot density symbols (red dots, 1 dot = 950 lbs=431 kg) display pounds caught per 10-minute square. 950 lbs is the median value of pounds landed per trip during 2001-2006, therefore, squares with more dots reported higher landings. Effort, the number of trips per 10-minute square, is displayed in the background as the blue color palette.
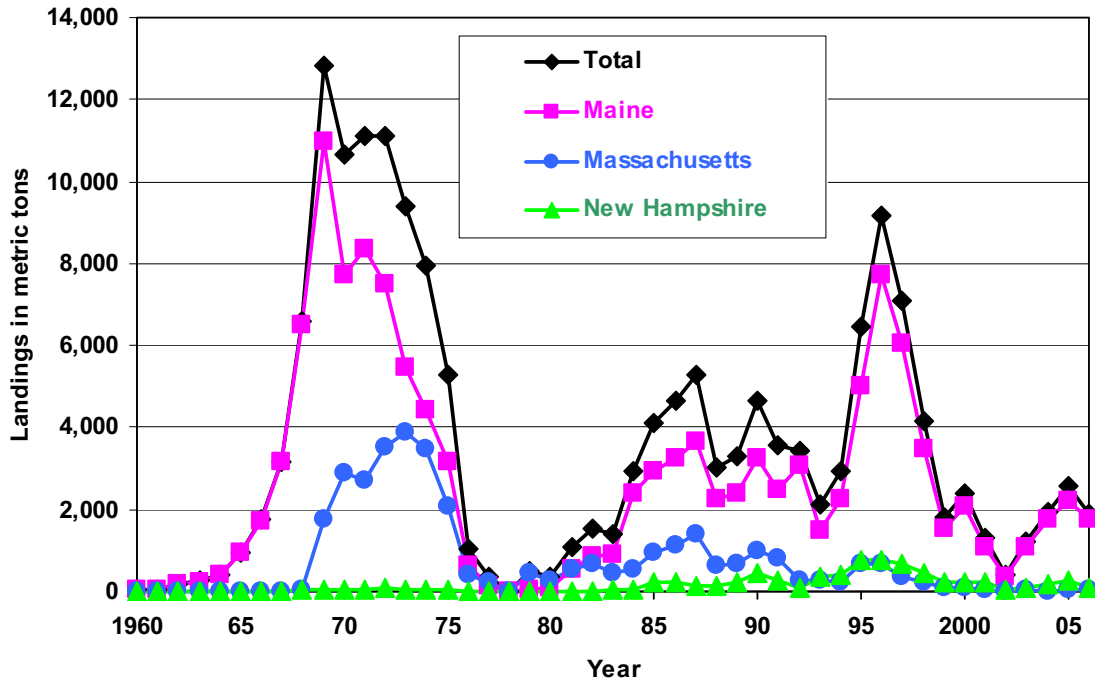
Figure A5-1. Gulf of Maine northern shrimp landings by year and state. (1 metric ton = 2,205 lbs)
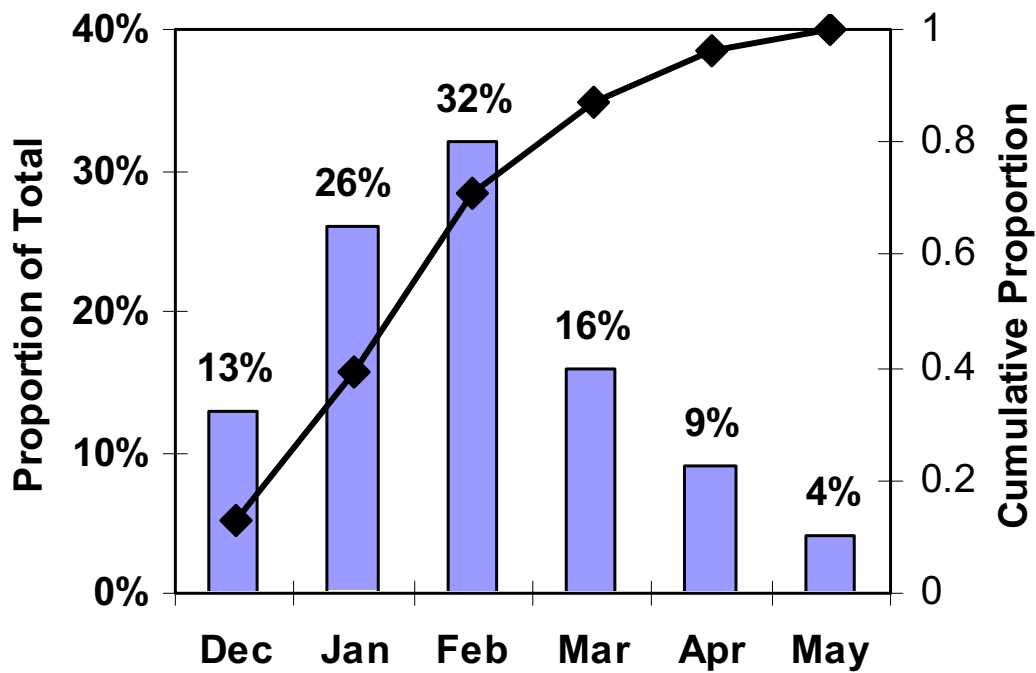

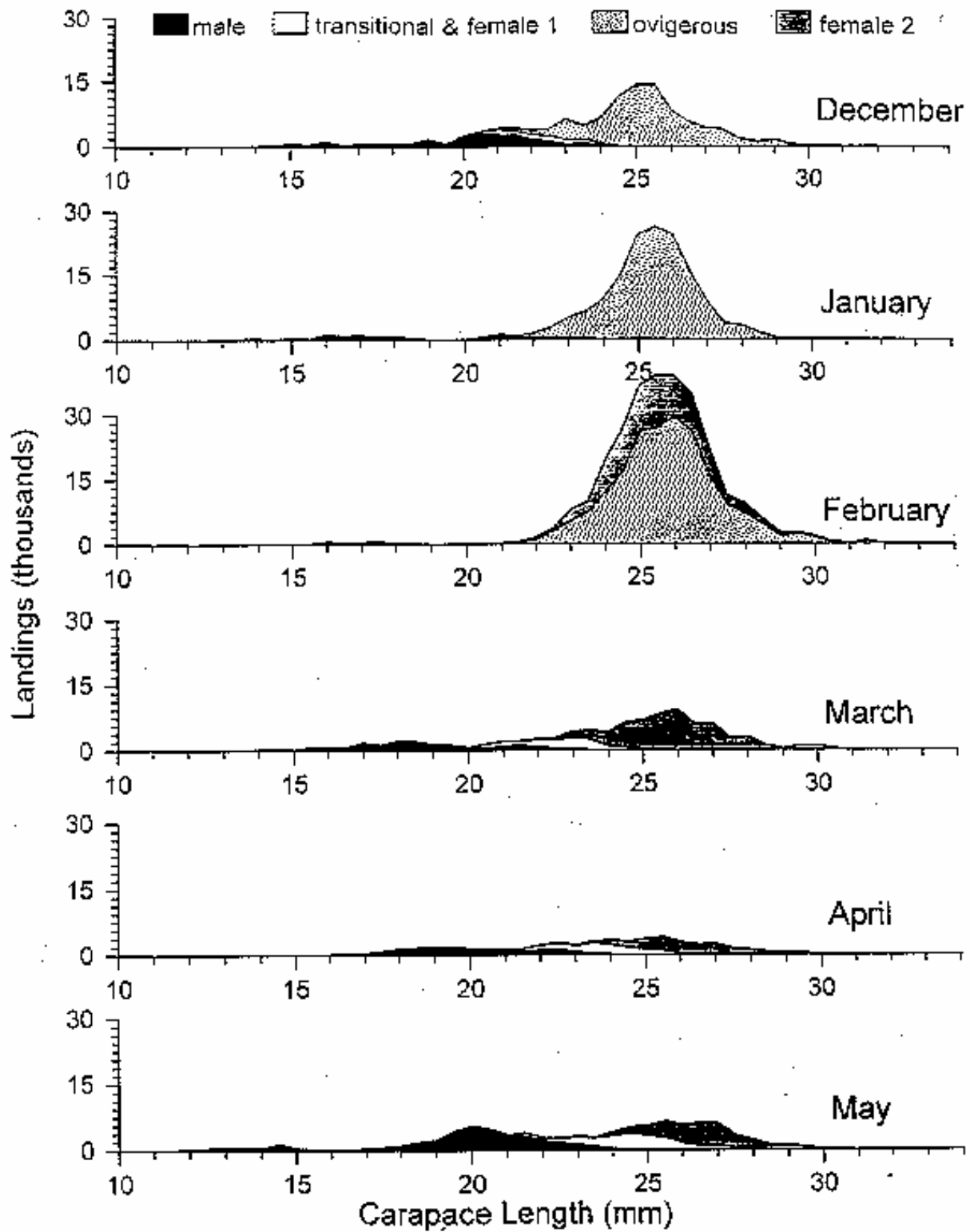Figure A5-2. Distribution of monthly landings of Gulf of Maine northern shrimp, 1984–1996.

Figure A5-3. Gulf of Maine northern shrimp landings by length, developmental stage, and month, 1996 fishing season.
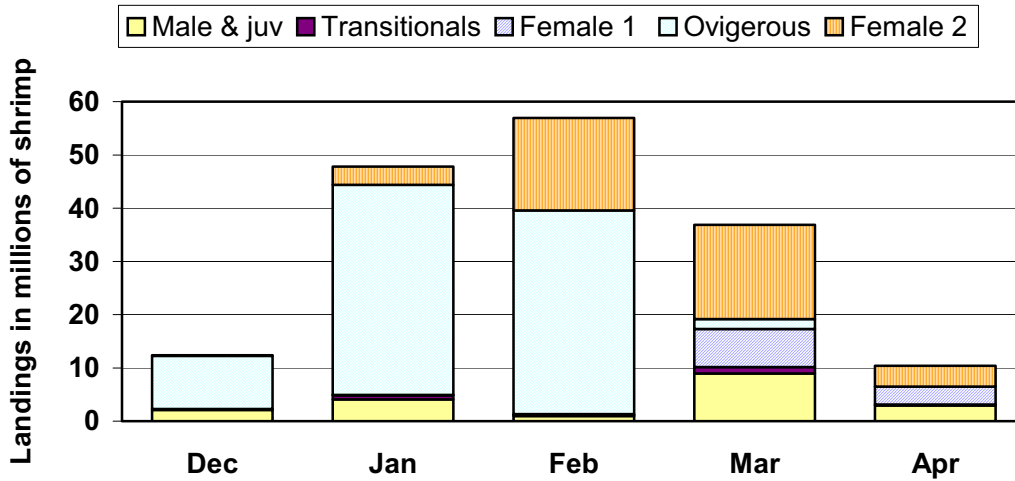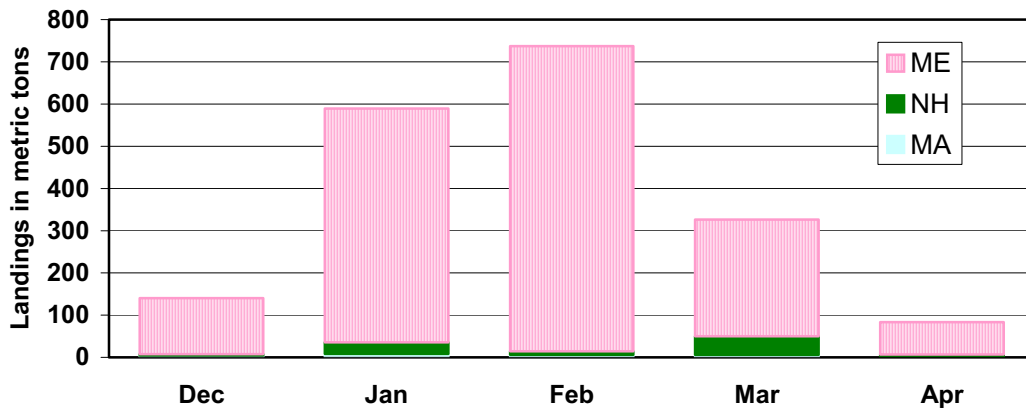
Figure A5-4. Gulf of Maine northern shrimp landings by month in the 2006 season. Landings are in metric tons by month and state (above), and in millions of shrimp by development stage (below). Landings are preliminary. (1 metric ton = 2,205 lbs)
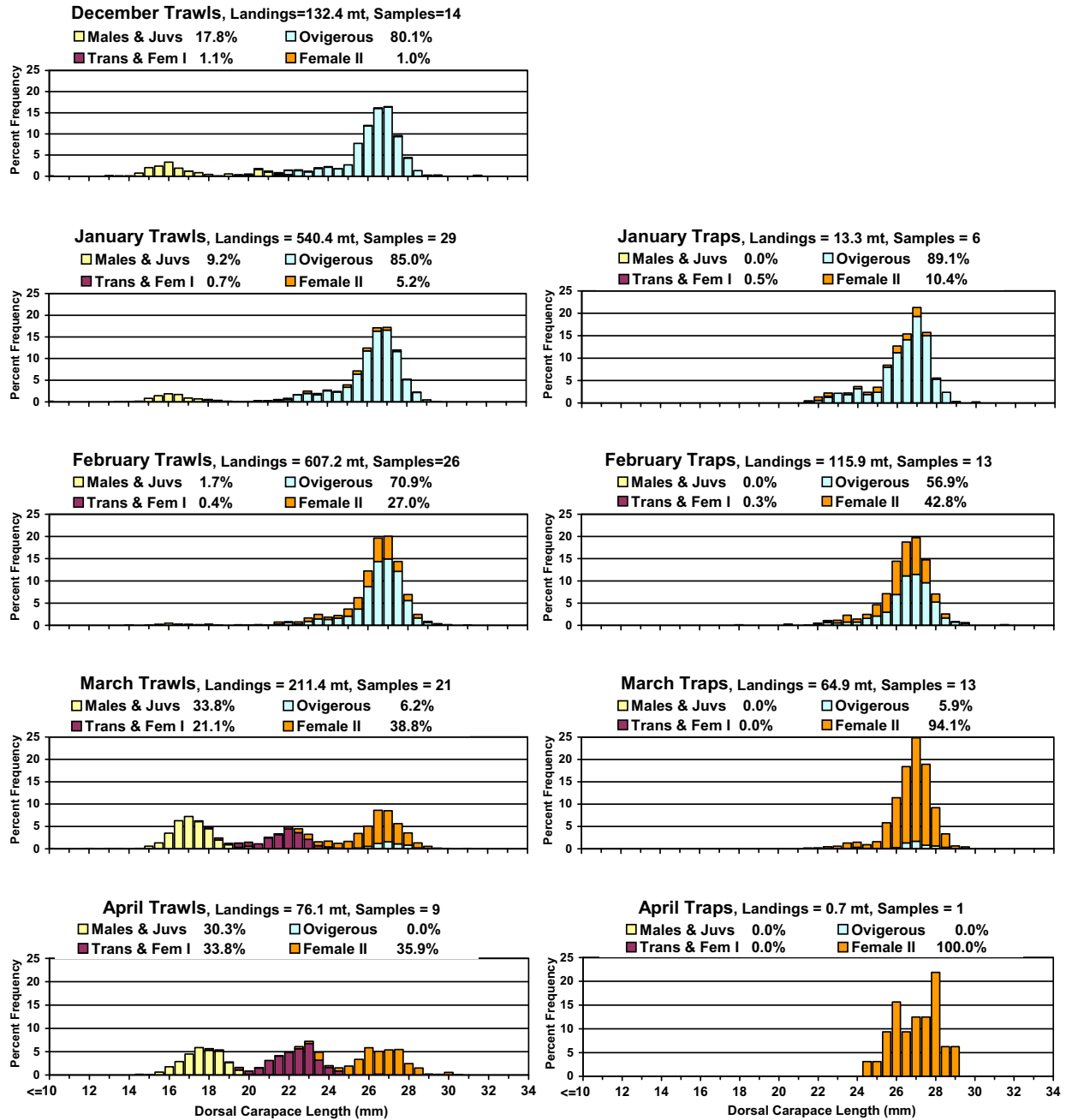
Figure A5-5. Length-frequency distribution from samples of Maine northern shrimp catches during the 2006 season by gear type and development stage. Landings are preliminary. (1 metric ton = 2,205 lbs)

December, Landings = 7.9 mt, Samples = 3

□ Males & Juvs 3.4%   □ Ovigerous 85.1%
■ Trans & Fem I 8.6%   ■ Female II   2.9%

January, Landings = 35.9 mt, Samples = 5

□ Males & Juvs 2.9%   □ Ovigerous 47.9%
■ Trans & Fem I 16.3%   ■ Female II 32.9%

February, Landings = 14.1 mt, Samples = 9

□ Males & Juvs 11.5%   □ Ovigerous   7.9%
■ Trans & Fem I 10.0%   ■ Female II 70.6%

March, Landings = 49.9 mt, Samples = 10

□ Males & Juvs 8.3%   □ Ovigerous   0.3%
■ Trans & Fem I 36.0%   ■ Female II 55.4%

April, Landings = 6.5 mt, Samples = 4

□ Males & Juvs 5.0%   □ Ovigerous   0.0%
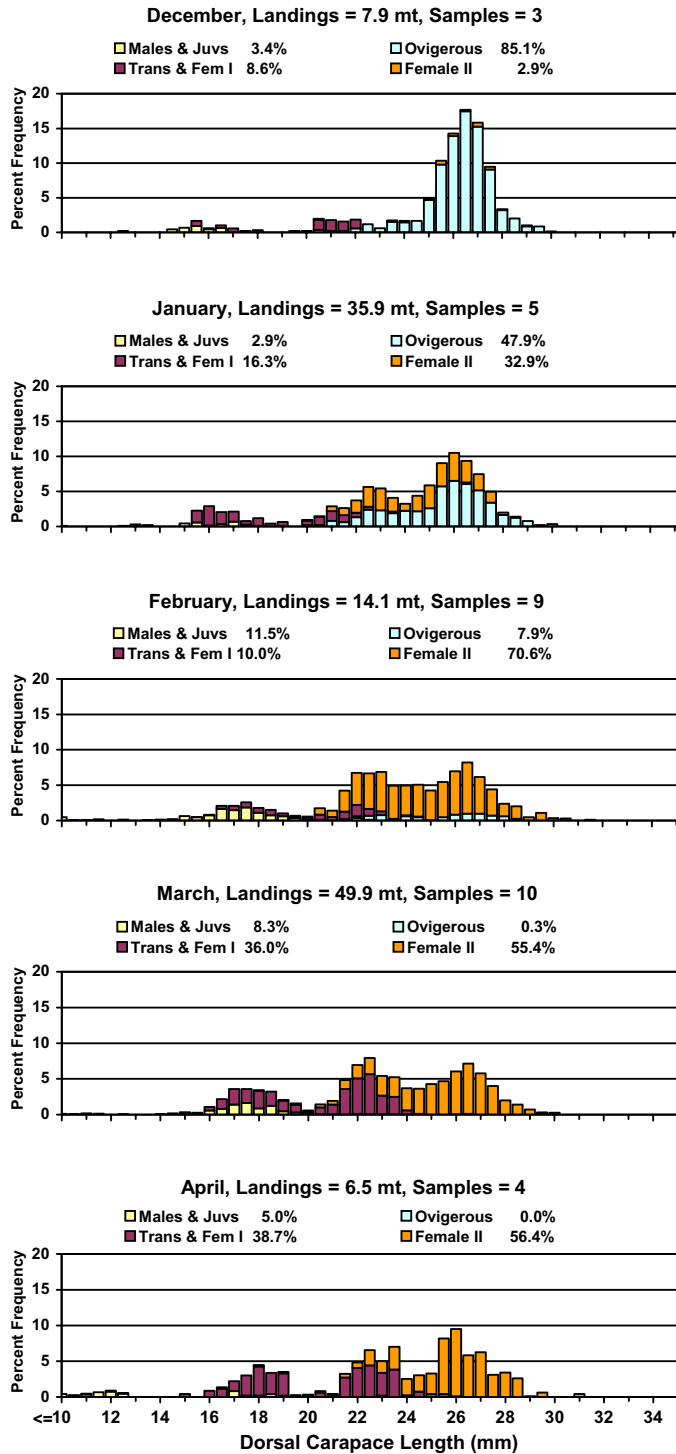■ Trans & Fem I 38.7%   ■ Female II 56.4%

Dorsal Carapace Length (mm)

Figure A5-6. Size-frequency distribution from samples of Massachusetts and New Hampshire northern shrimp catches during the 2006 season by development stage. Landings are preliminary. (1 metric ton = 2,205 lbs)

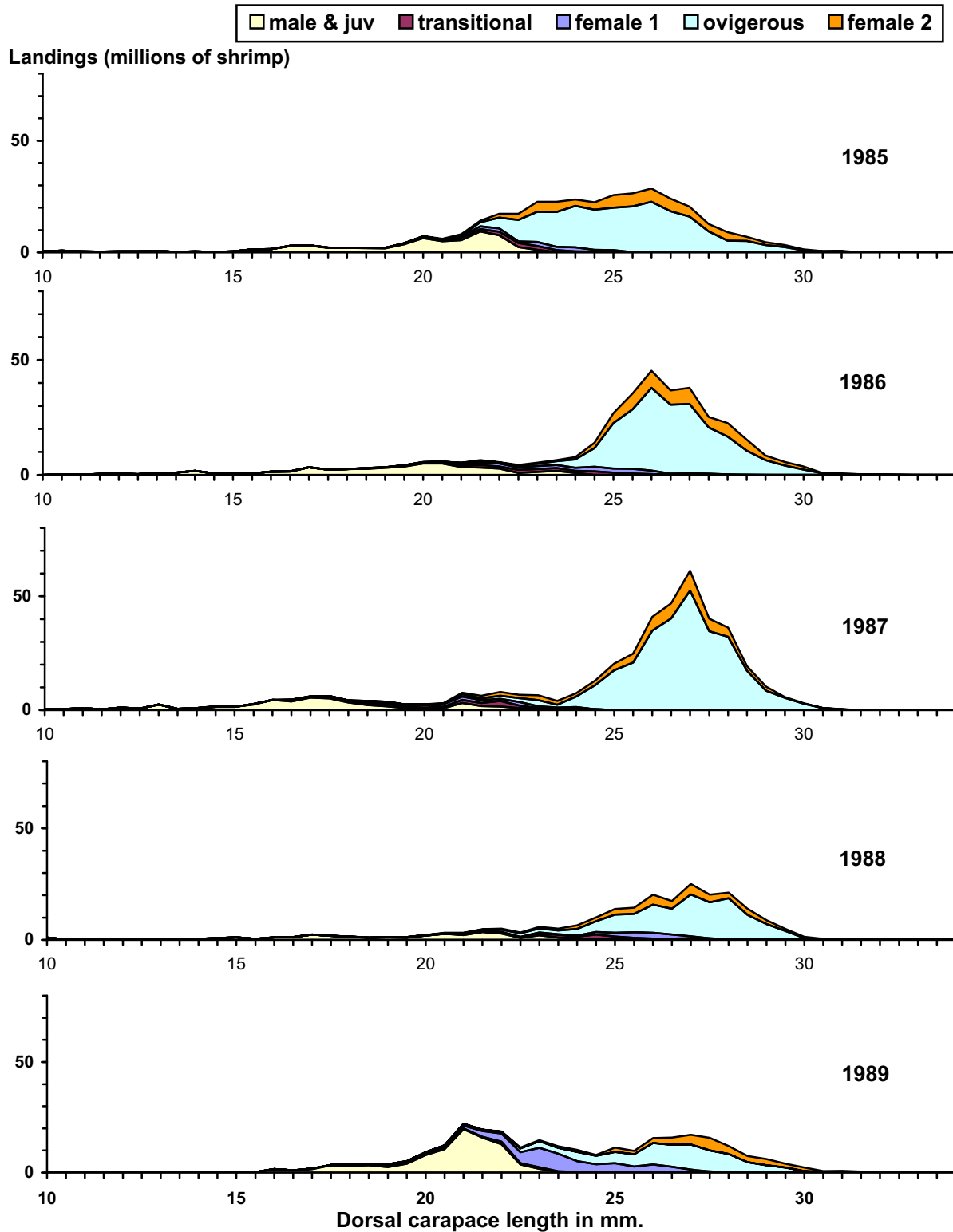**Landings (millions of shrimp)**

Figure A5-7. Gulf of Maine northern shrimp landings in numbers of shrimp, by length, stage, and fishing season. Landings are preliminary throughout.
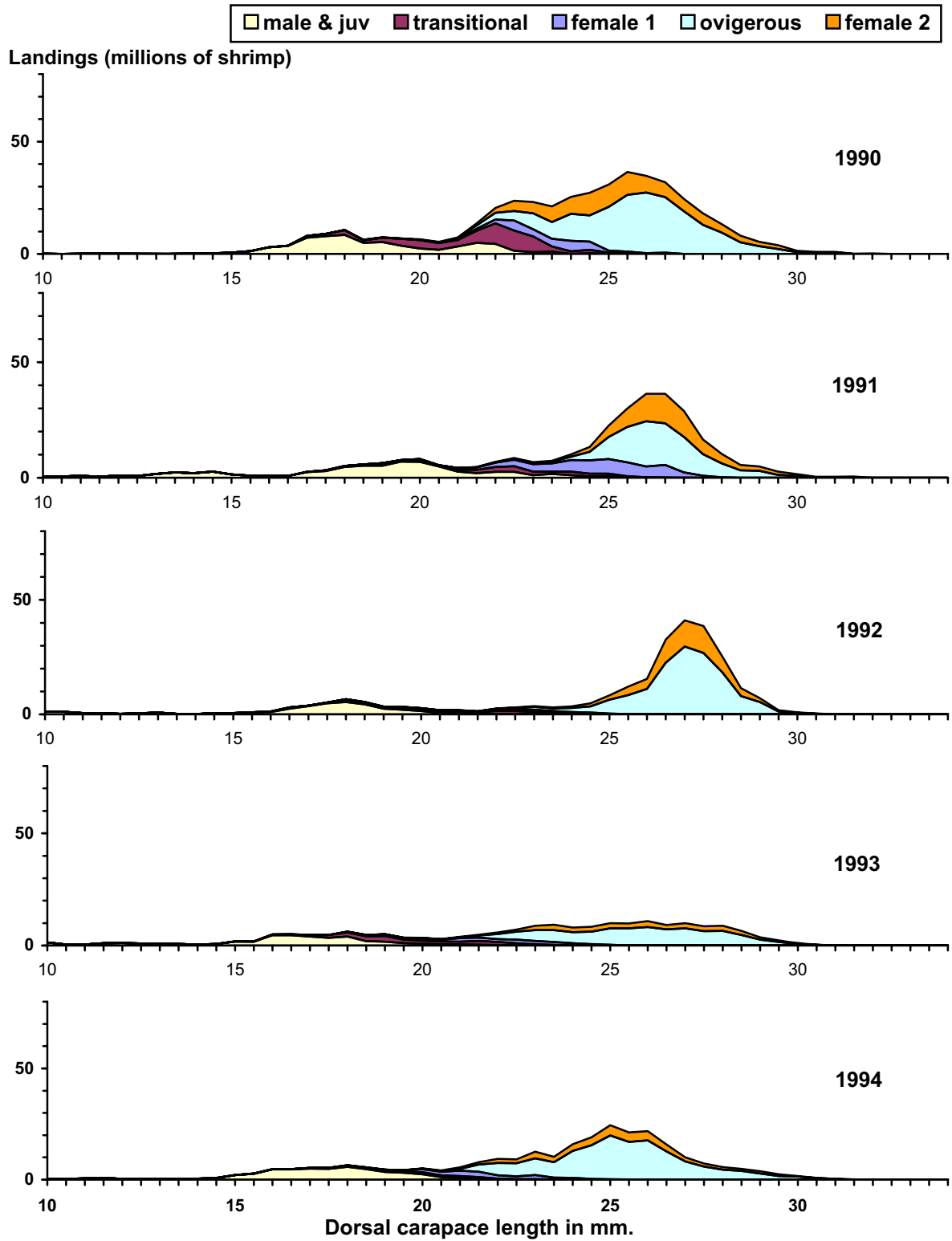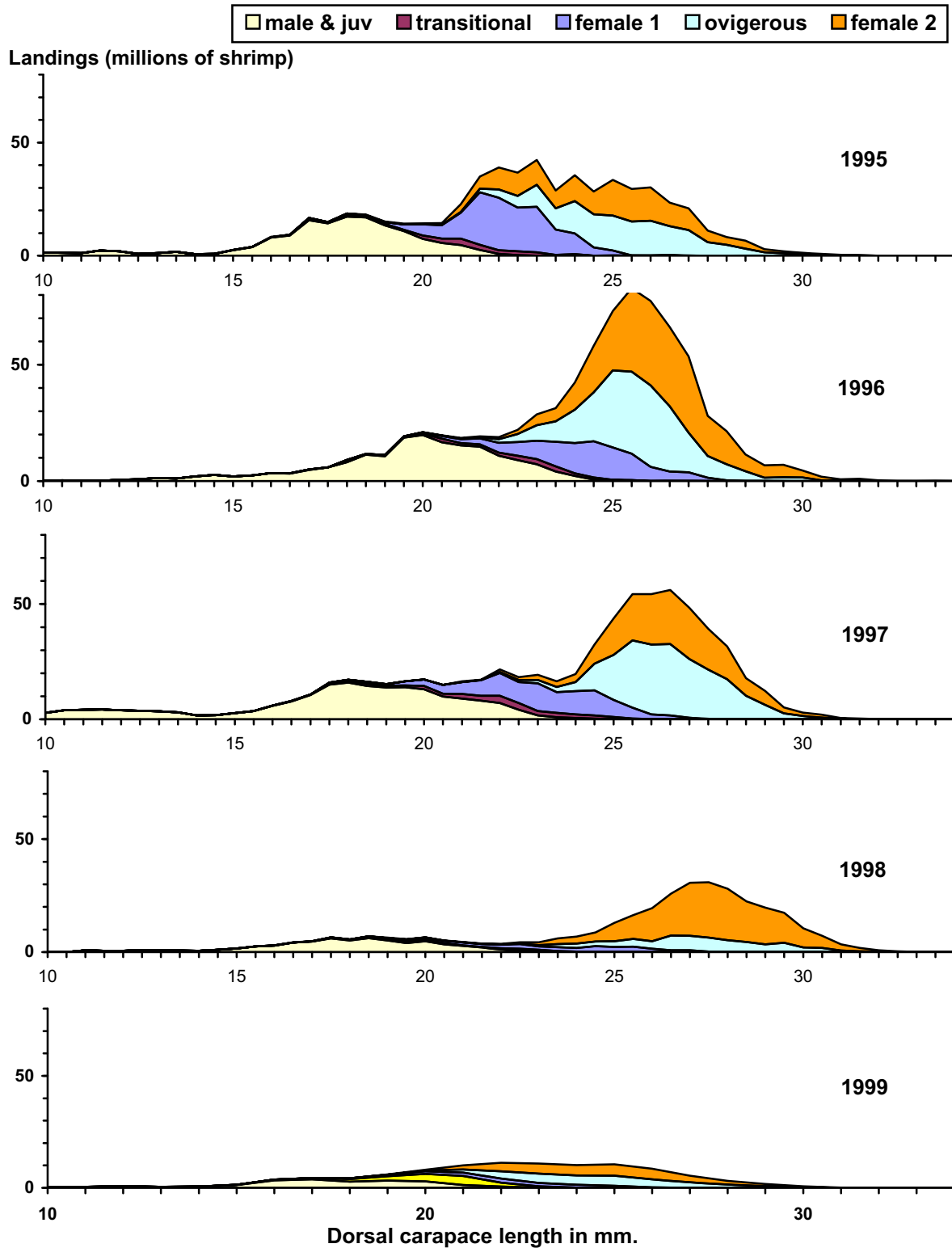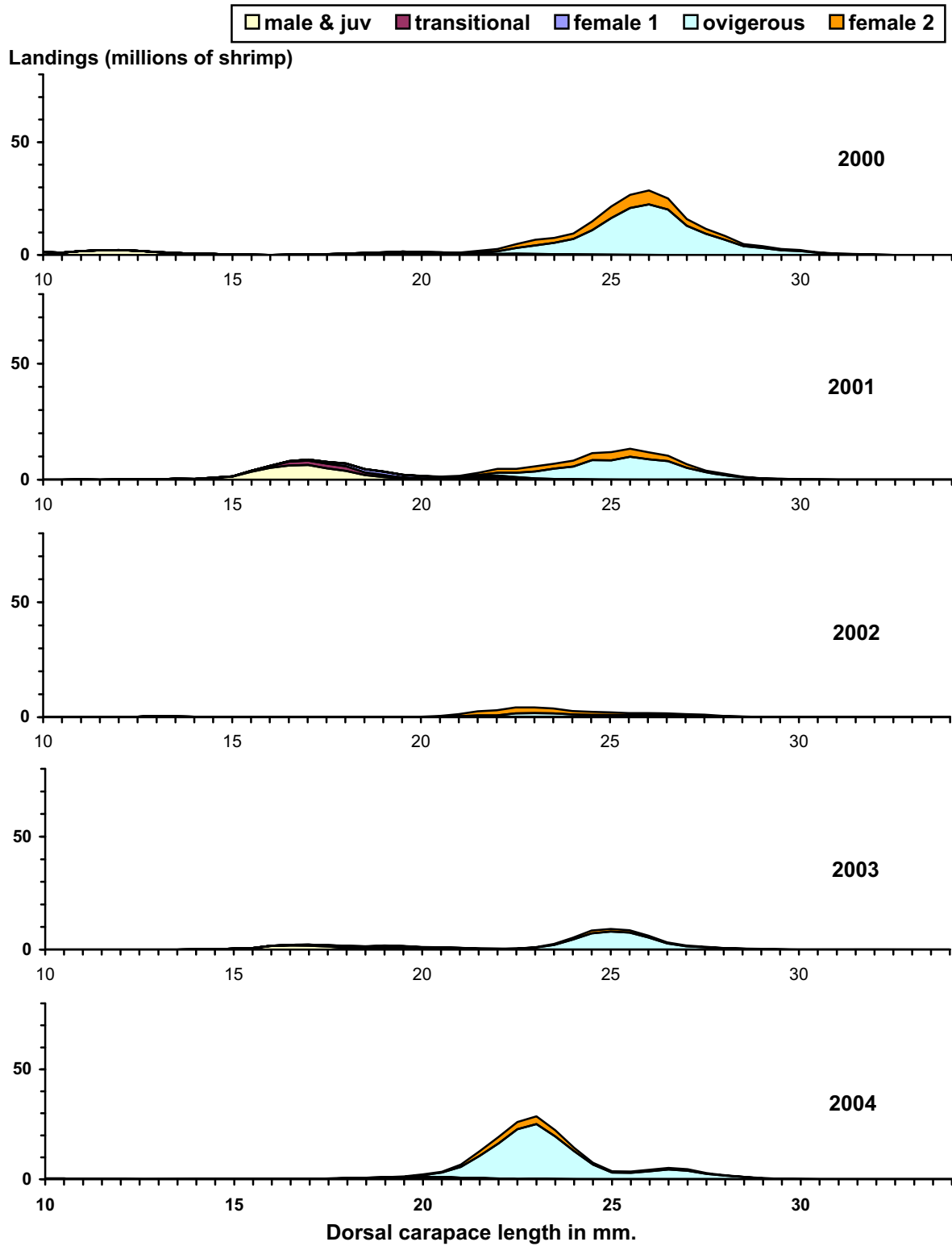
Figure A5-7 continued.

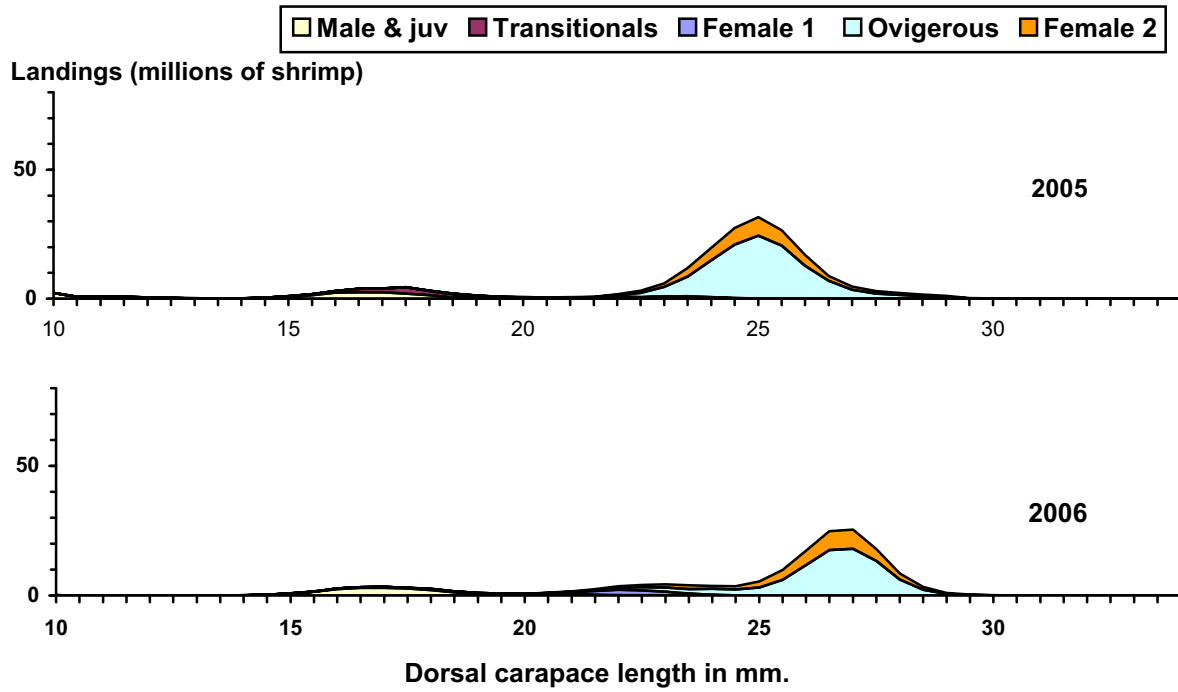Figure A5-7 continued.

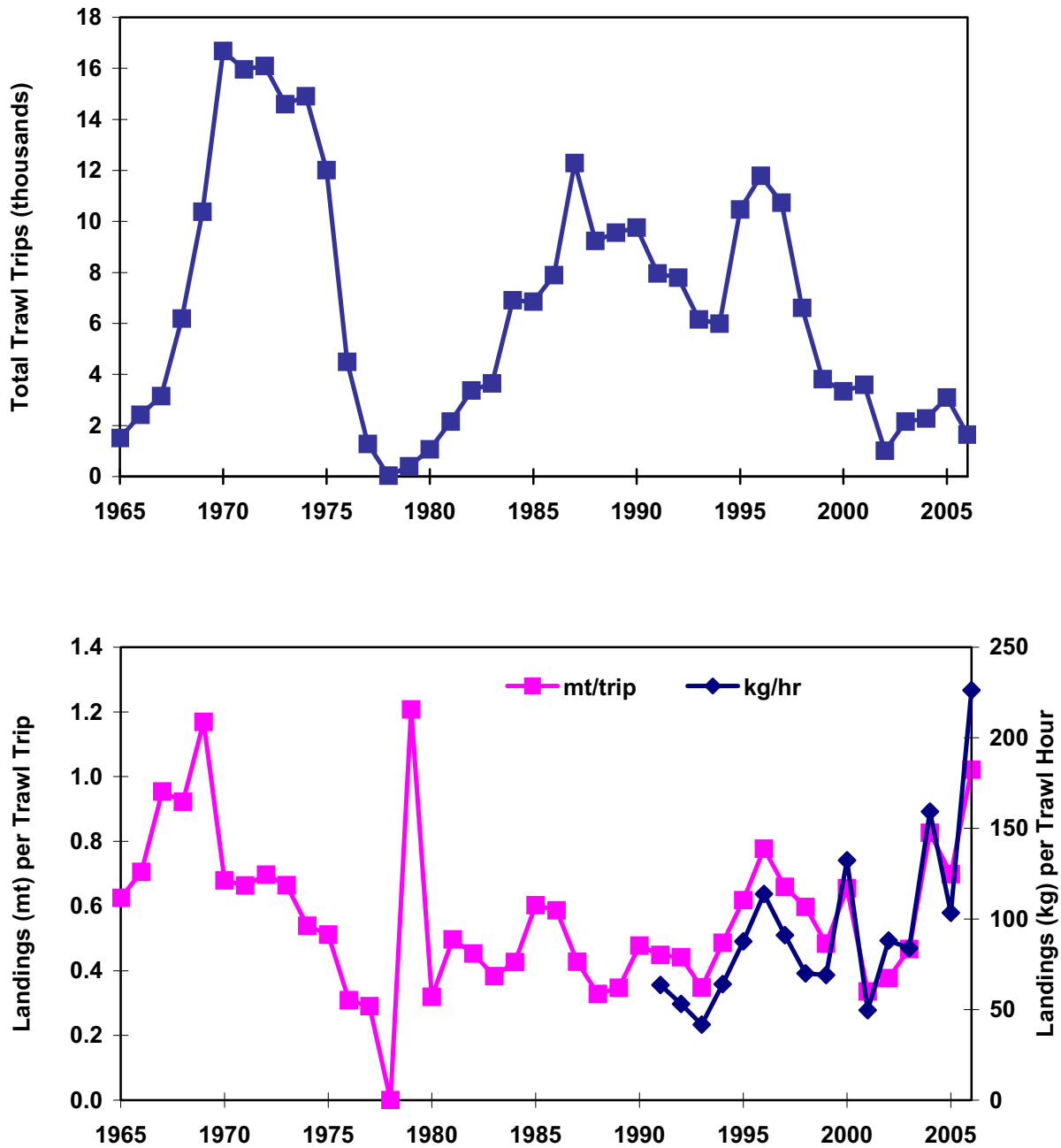Figure A5-7 continued.

Figure A5-7 continued.

Figure A5-8. Nominal fishing effort (trawl trips) (above) and catch per unit effort (below), in the Gulf of Maine northern shrimp fishery by year. 2005 and 2006 data are preliminary. (1 mt = 2,205 lbs, 1 kg = 2.2 lbs)
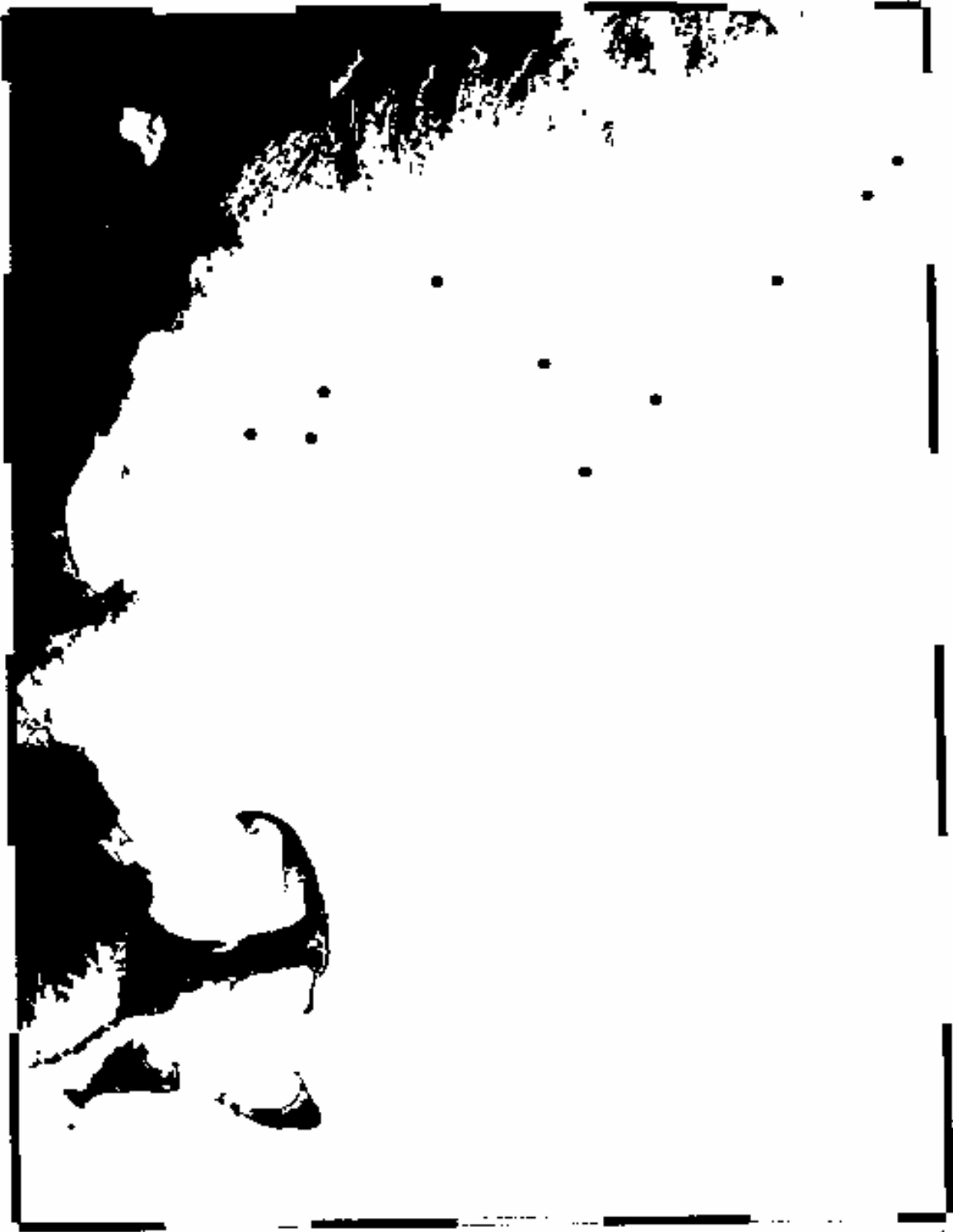
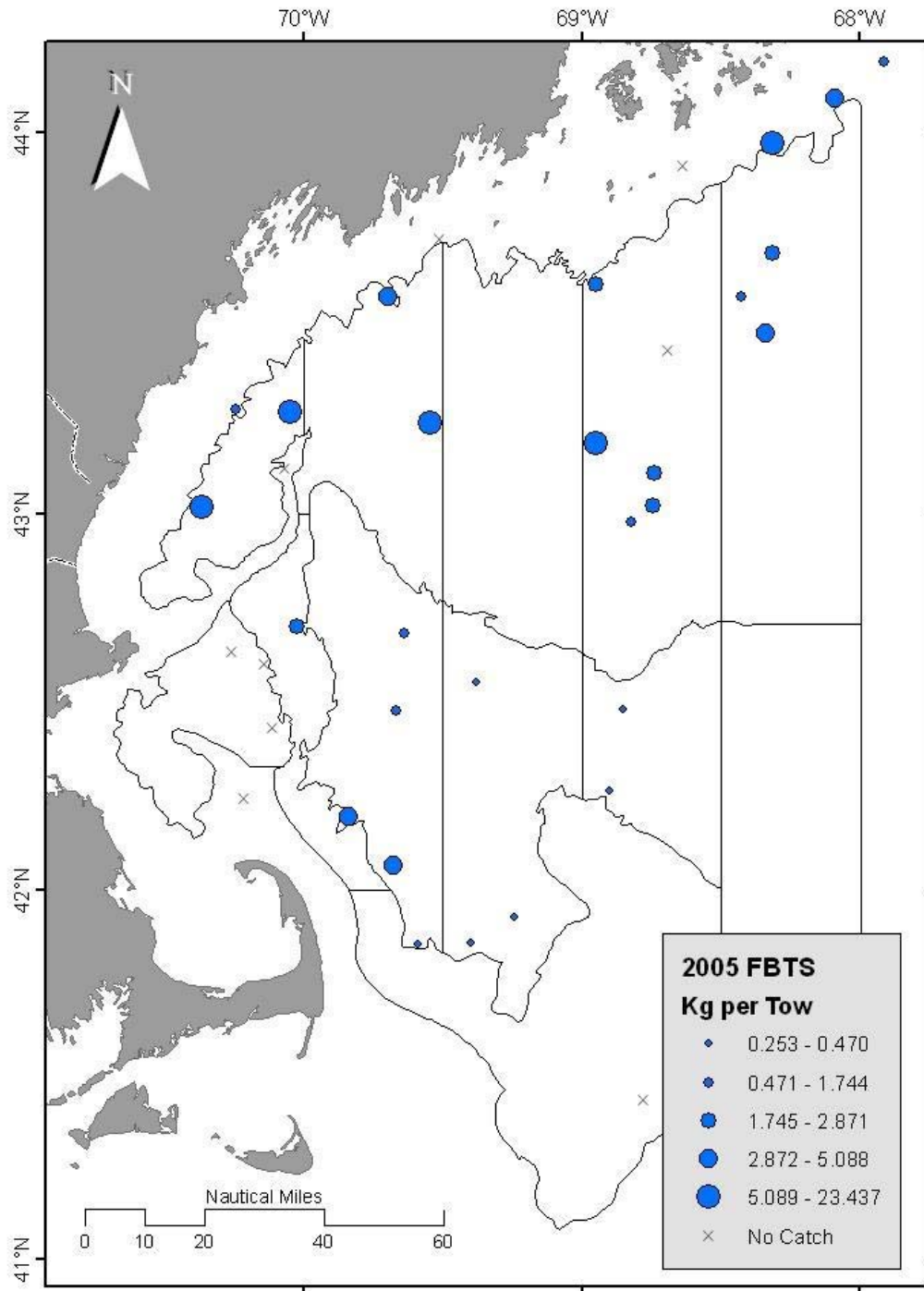Figure A6-1. State of Maine summer northern shrimp survey station locations.

Figure A6-2. Northern shrimp survey strata and observed distribution of catch (kg) per tow of northern shrimp collected during the 2005 autumn bottom trawl survey in the western Gulf of Maine aboard the R/V Albatross IV. (1 kg = 2.2 lbs)
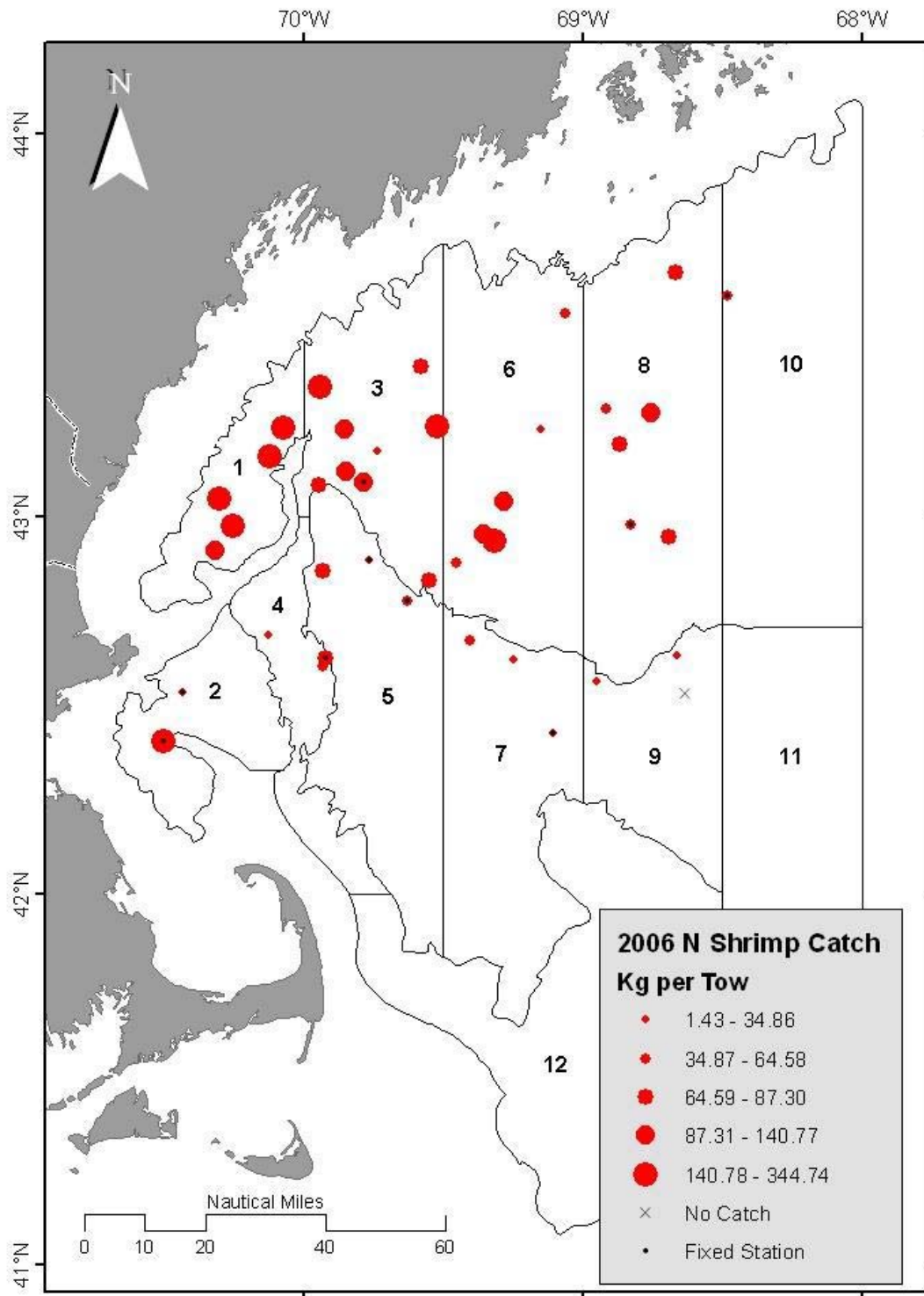
Figure A6-3. Northern shrimp survey strata and observed distribution of catch (kg) per tow of northern shrimp collected in the western Gulf of Maine aboard the R/V Gloria Michelle, July 24 – August 11, 2006. (1 kg = 2.2 lbs)
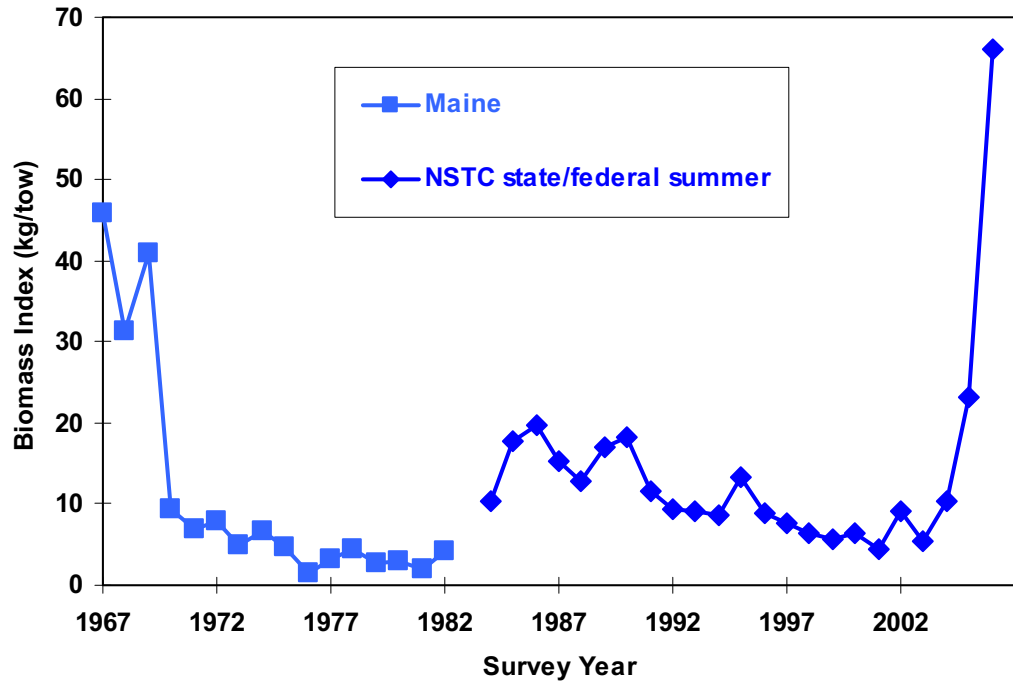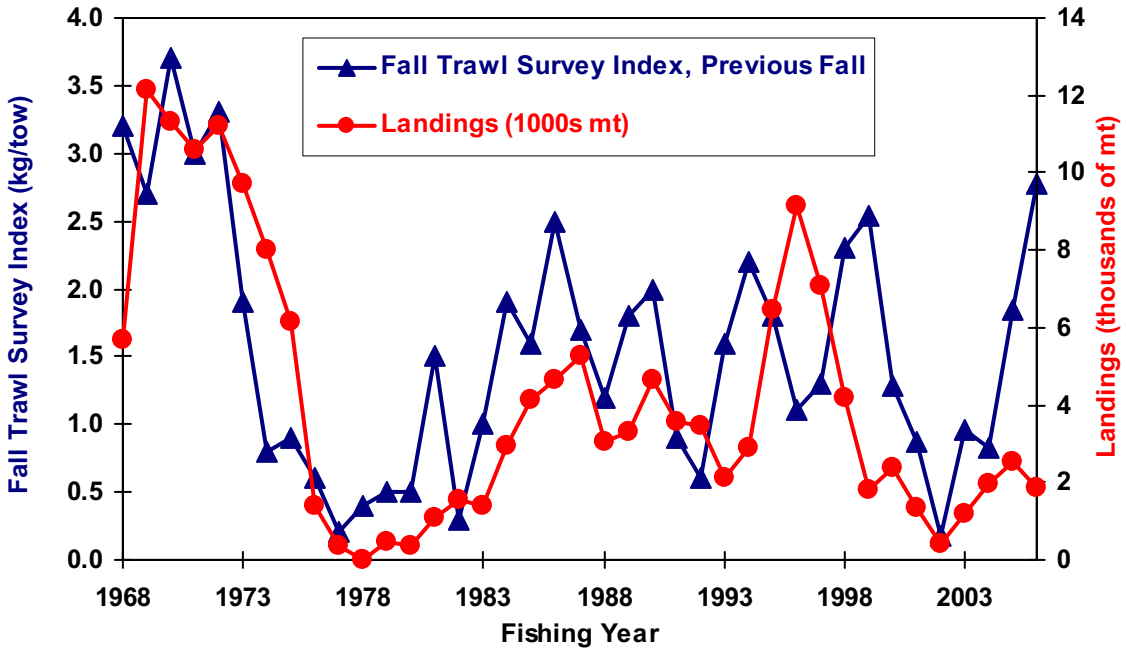
Figure A6-4. The "selectivity" method of deriving indices of abundance for fully-recruited and recruited Gulf of Maine northern shrimp from summer survey length frequencies. Example illustrated here is from 1996.

Figure A6-5. Research trawl survey indices (NEFSC fall trawl survey above; Maine and NSTC summer surveys below) and landings (above) of Gulf of Maine northern shrimp. (1 mt = 2,205 lbs, 1 kg = 2.2 lbs)
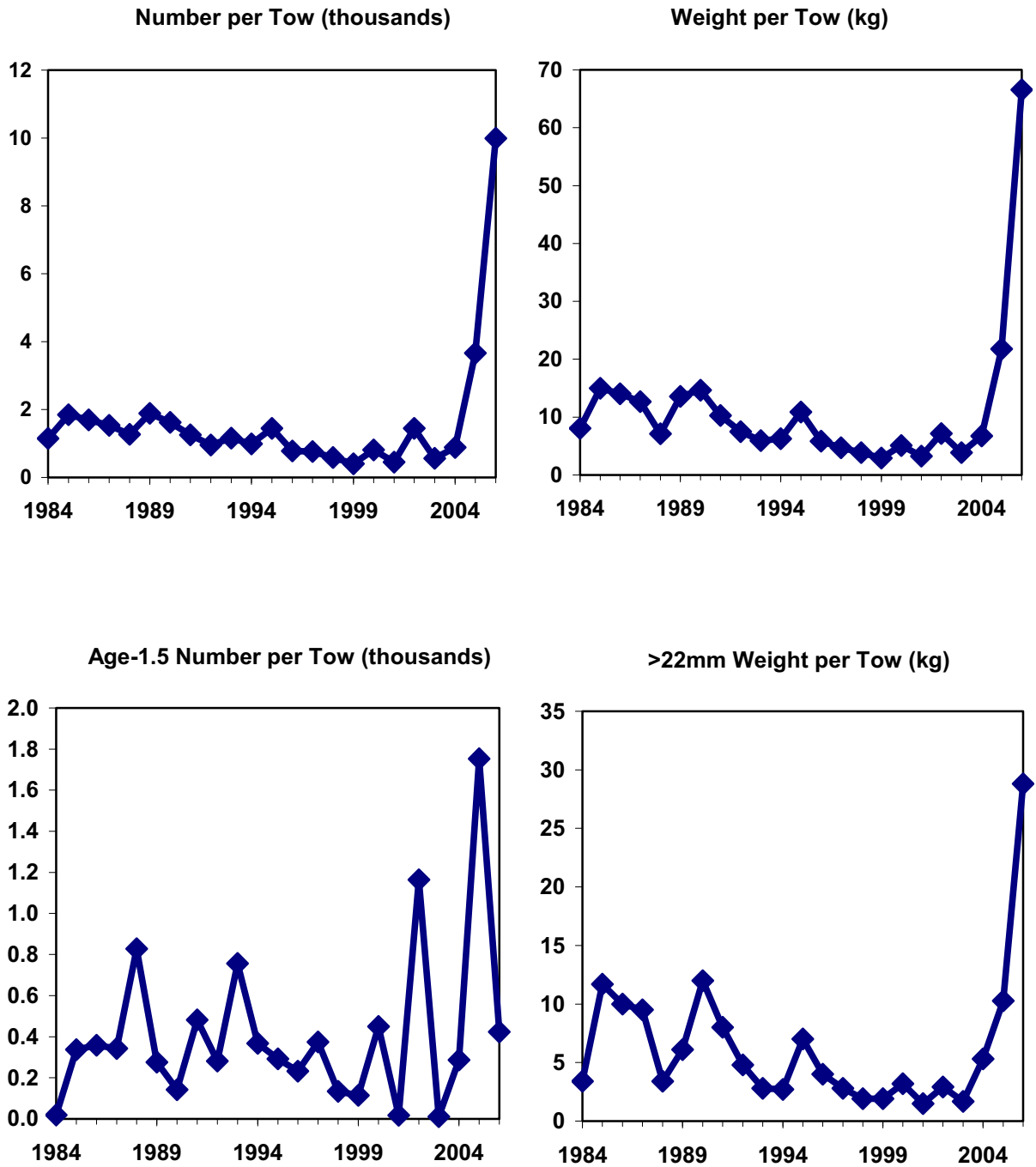
Figure A6-6. NSTC state/federal summer survey indices of abundance and biomass of Gulf of Maine northern shrimp. (1 kg = 2.2 lbs)
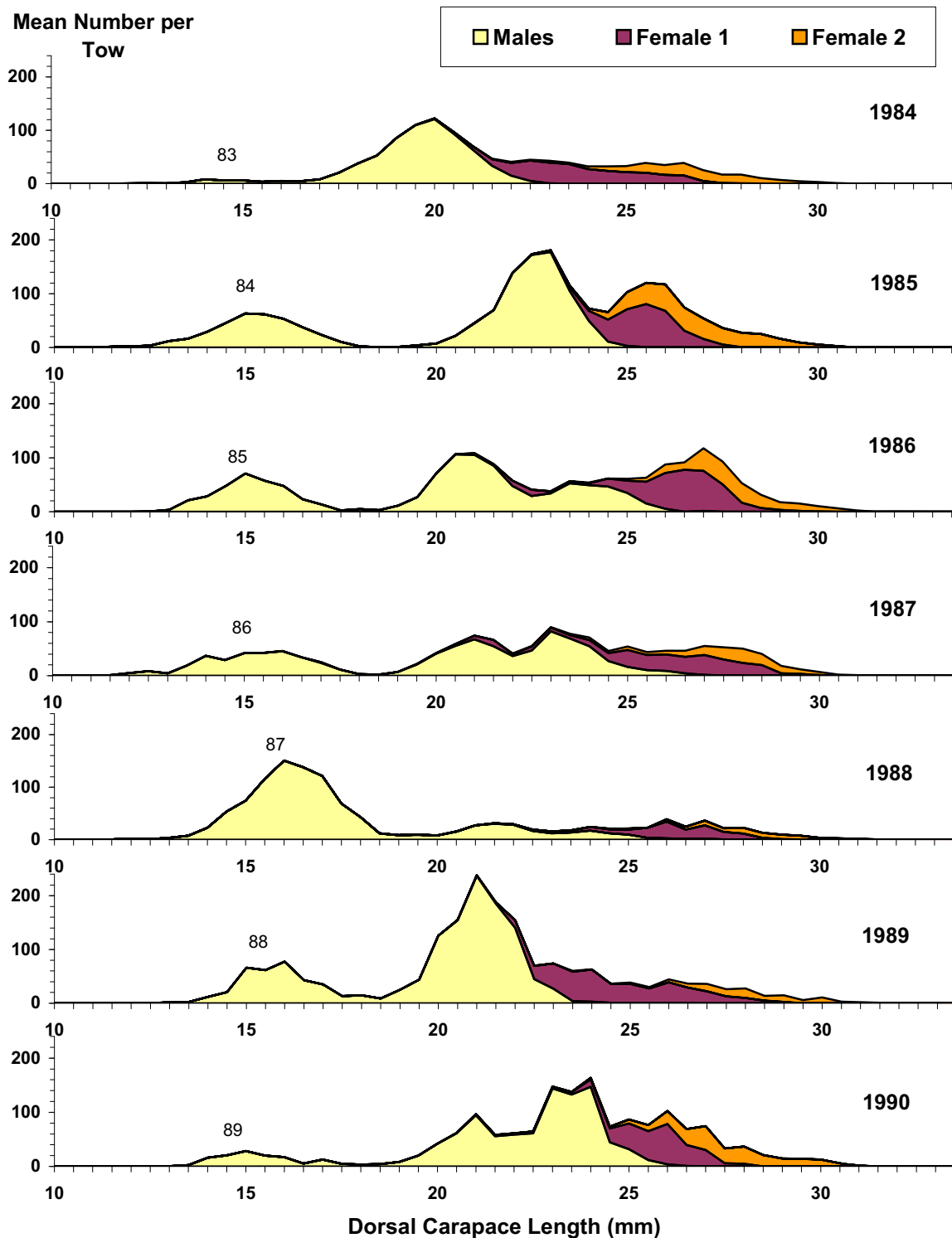
Figure A6-7. NSTC state/federal summer survey mean number caught per tow by survey year, length, and development stage for Gulf of Maine northern shrimp. Two-digit years are year class at assumed age 1.5.
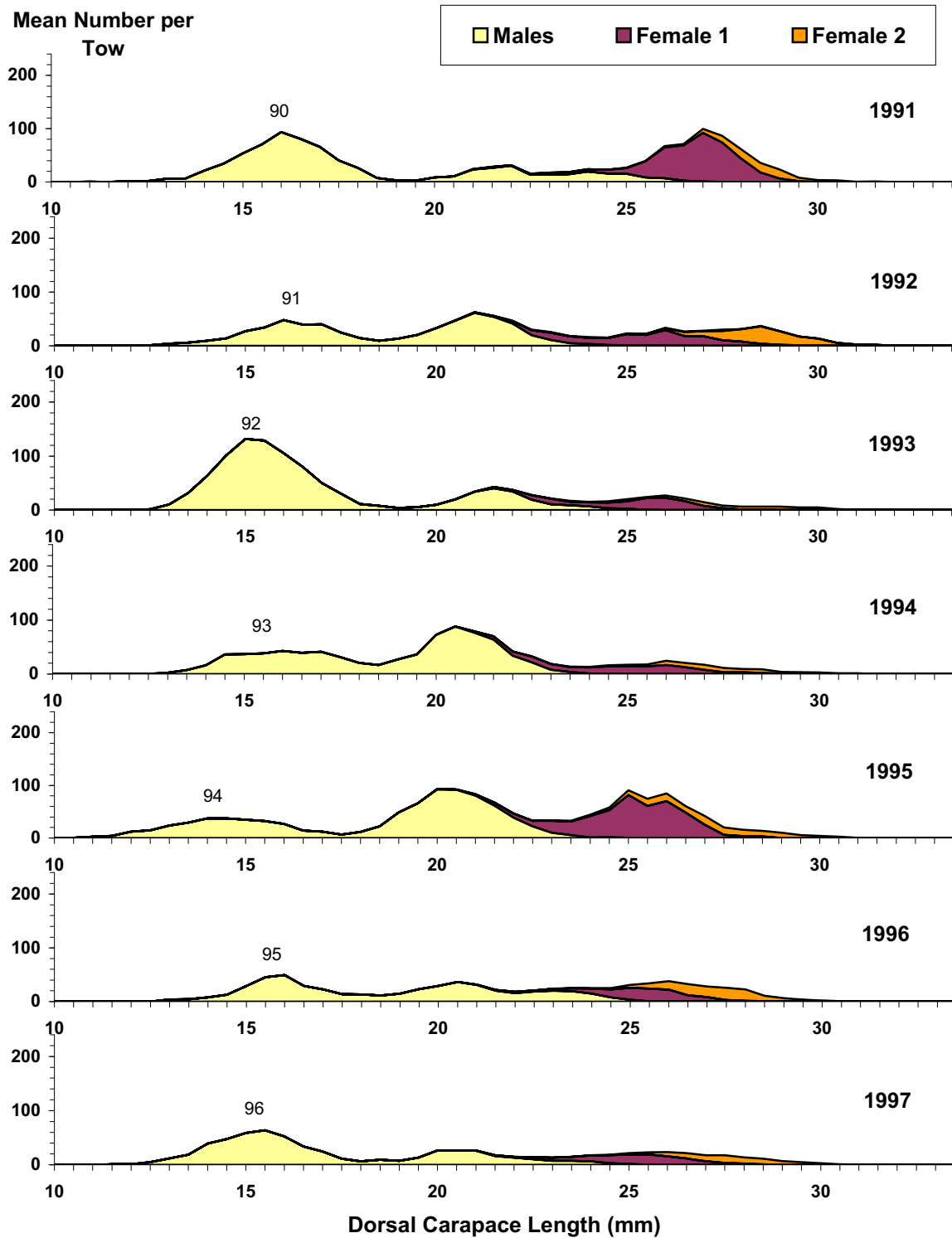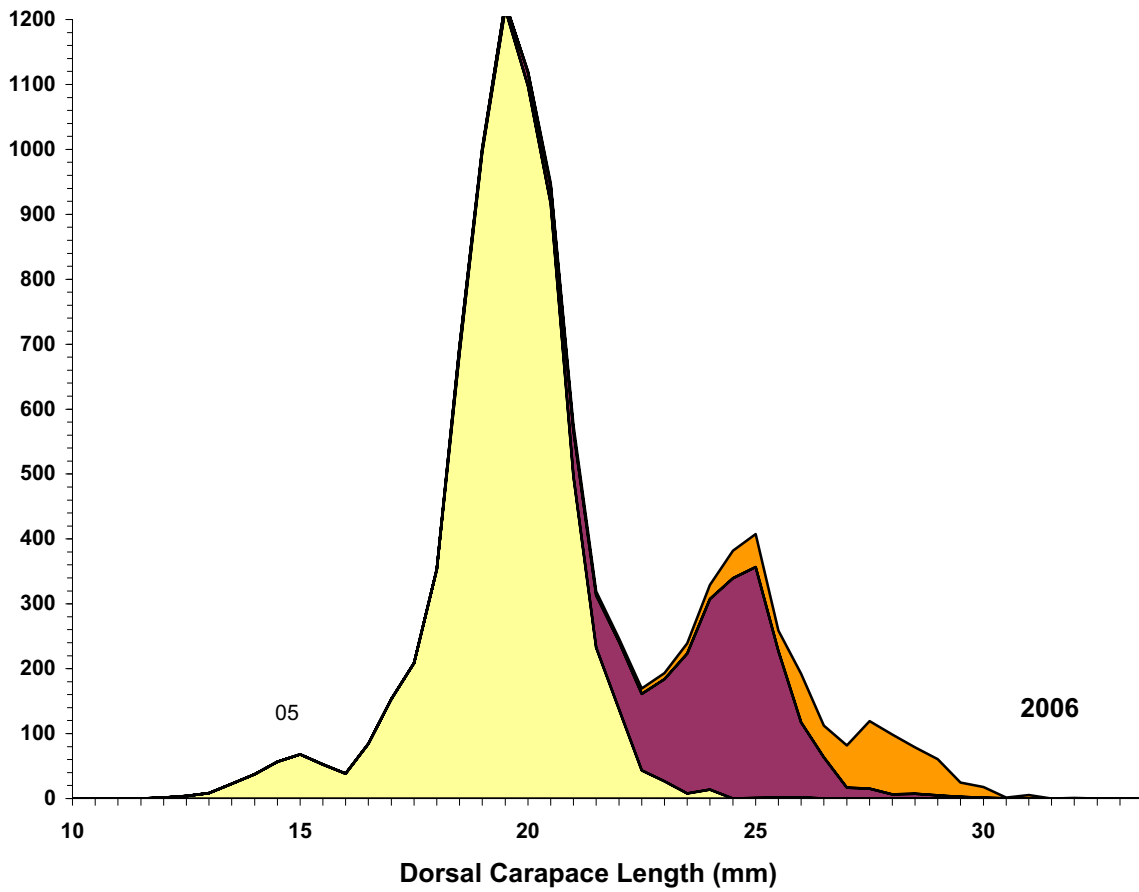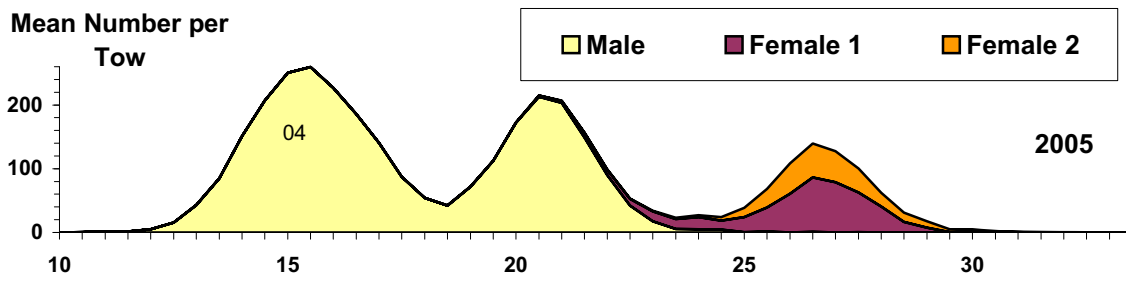
Figure A6-7 continued.
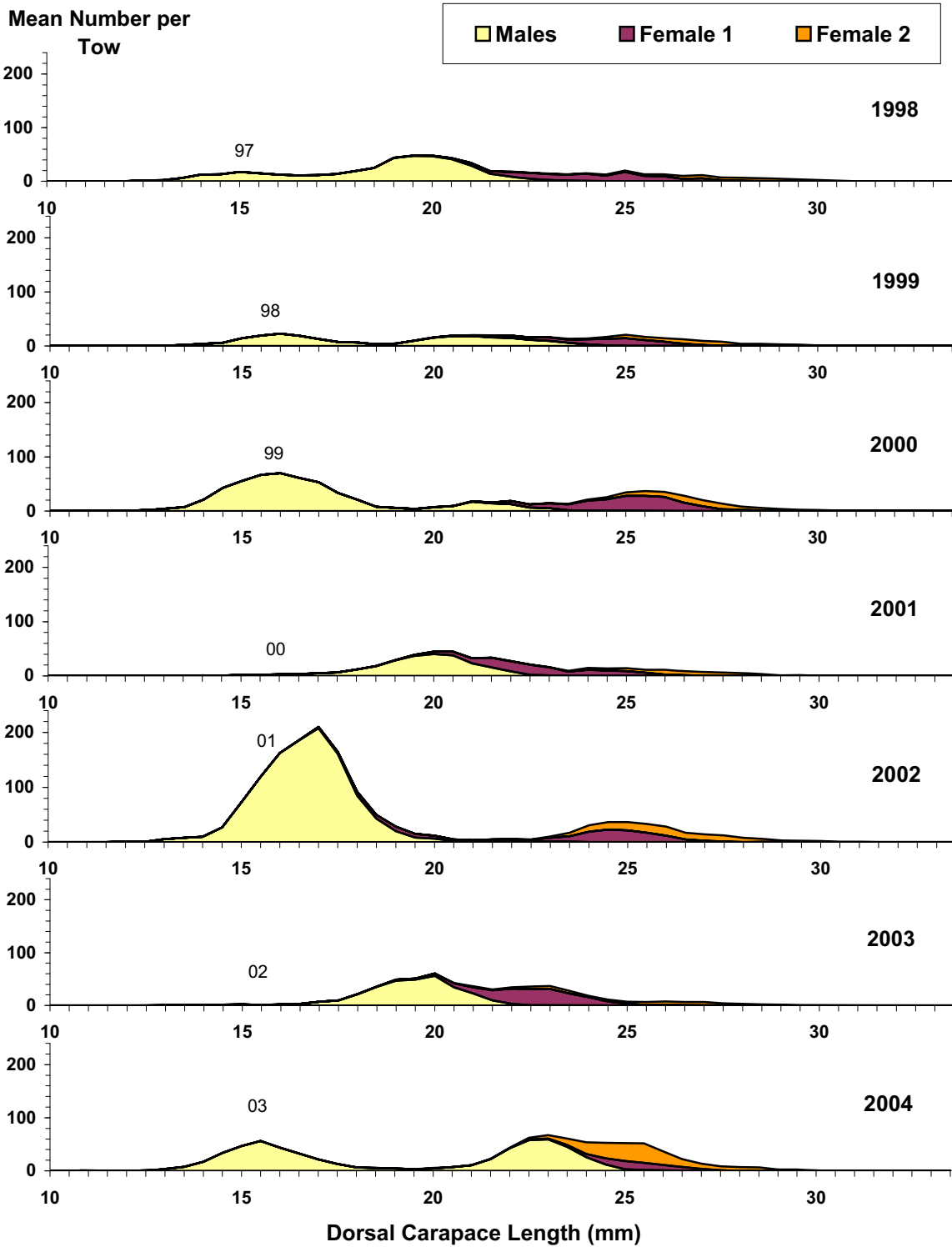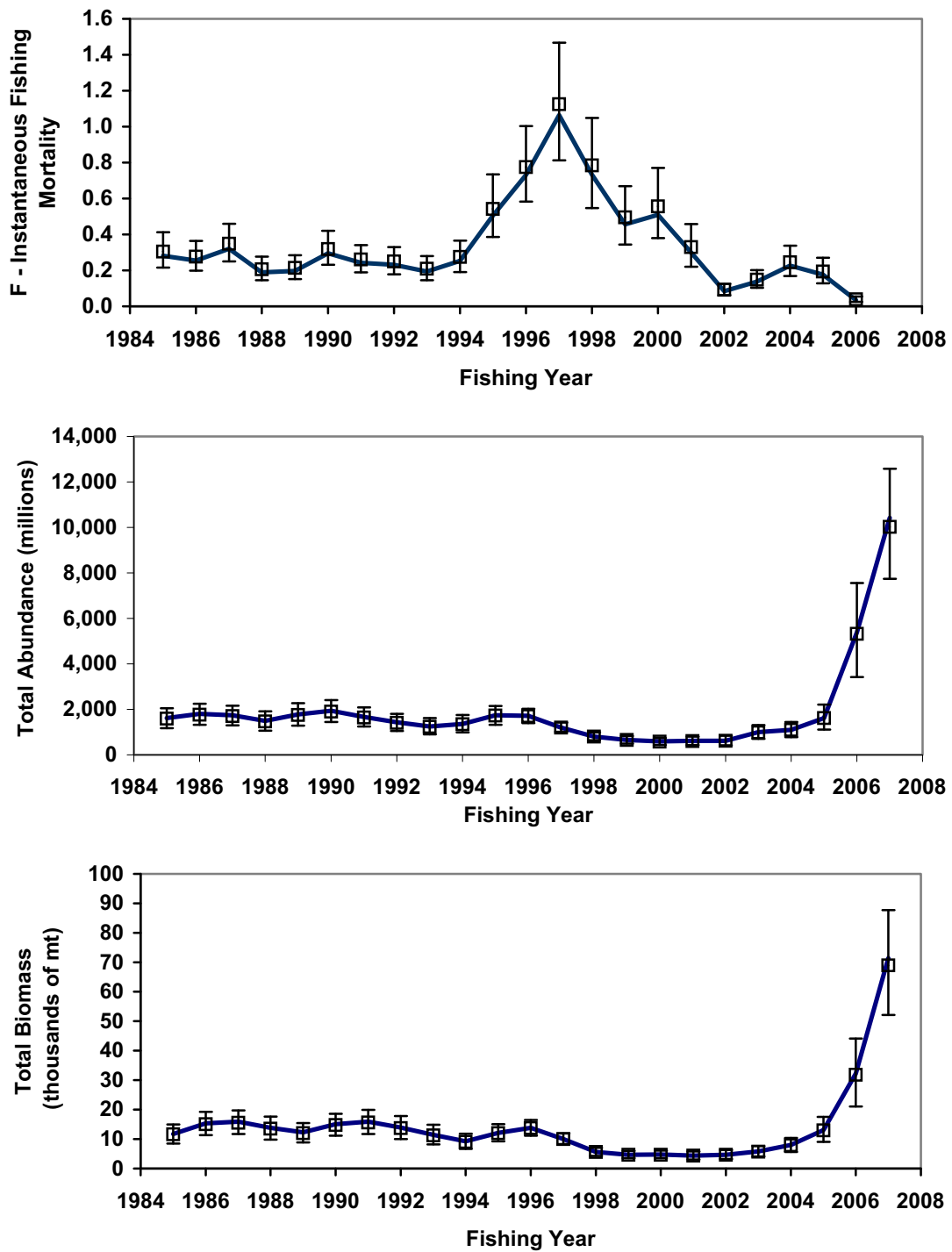
Figure A6-7 continued.

Figure A6-7 continued.

Figure A6-8. 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. M=0.25.
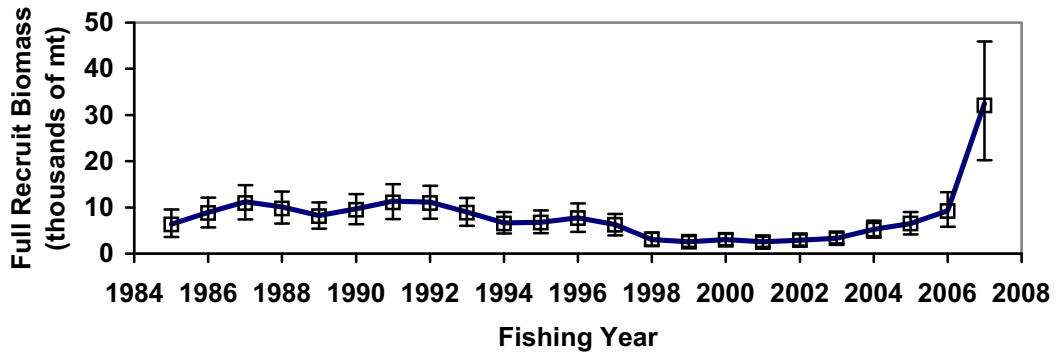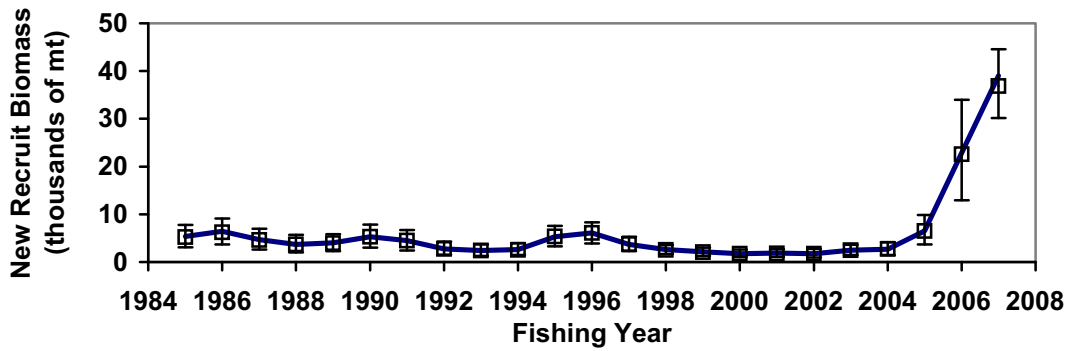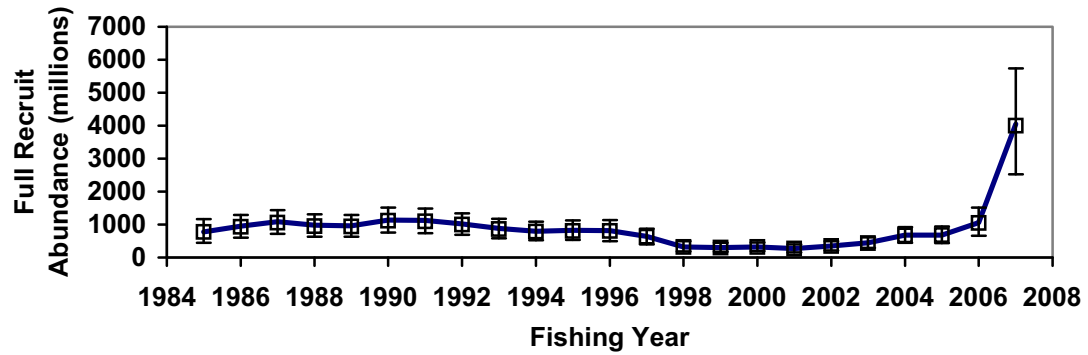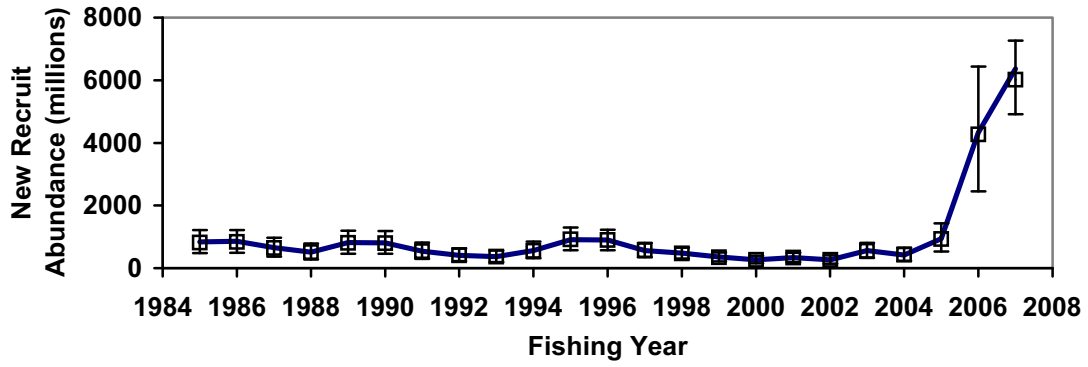
Figure A6-8 continued.

Input Data using Summer Survey			
	Indices of Abundance		Total Catch Millions*
Survey Year*	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	233.98
2005	1295.2	1231.7	163.62
2006	3906.5	3899.9	

* Survey Year data are applied to the following Fishing Year

Results			
Stock Size Estimates millions at time of Survey		Fishing Mortality All sizes	Total Mortality Z all sizes
Recruits	Full Recruits		
838.6	776.6	0.28	0.53
854.6	949.2	0.26	0.51
652.4	1088.6	0.32	0.57
509.6	984.0	0.19	0.44
820.2	962.9	0.20	0.45
802.7	1140.0	0.30	0.55
544.8	1126.0	0.24	0.49
405.6	1020.7	0.23	0.48
366.7	880.9	0.19	0.44
559.1	800.9	0.25	0.50
913.5	822.4	0.50	0.75
900.0	815.9	0.73	0.98
557.1	643.2	1.06	1.31
478.8	322.4	0.73	0.98
357.2	299.9	0.46	0.71
262.5	324.2	0.51	0.76
336.8	274.7	0.30	0.55
264.8	353.0	0.08	0.33
559.9	442.1	0.14	0.39
420.9	680.6	0.23	0.48
937.7	683.7	0.18	0.43
4330.5	1057.6	0.03	0.28
6362.7	4052.3		

Input File Name	R2006_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	0.6814 0.1817

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 2006
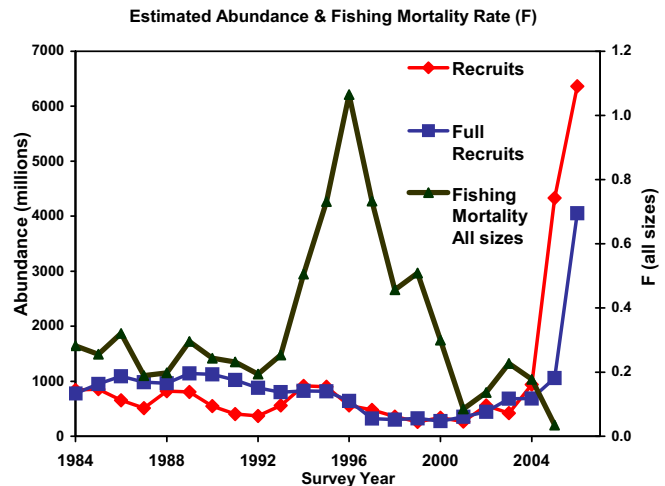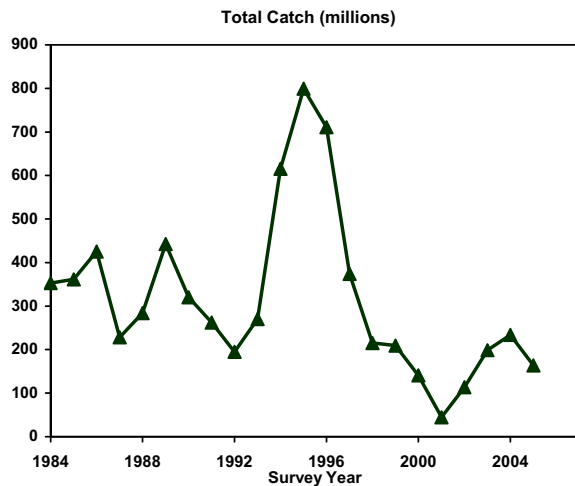

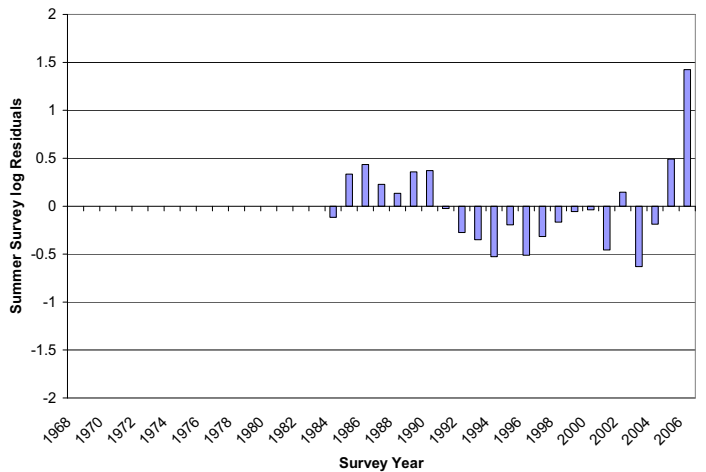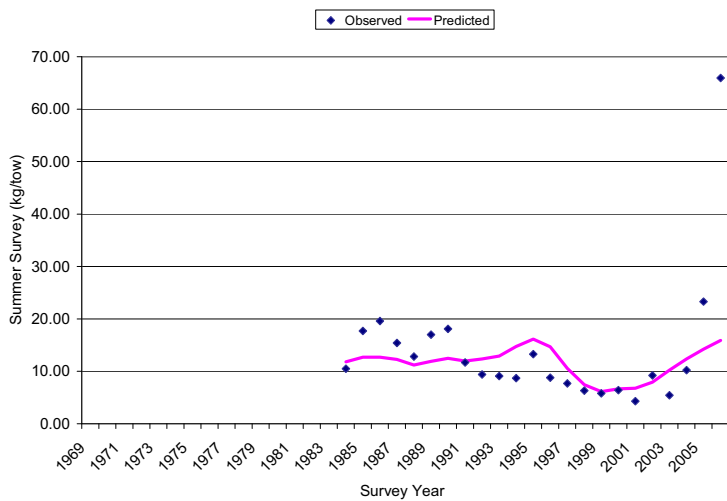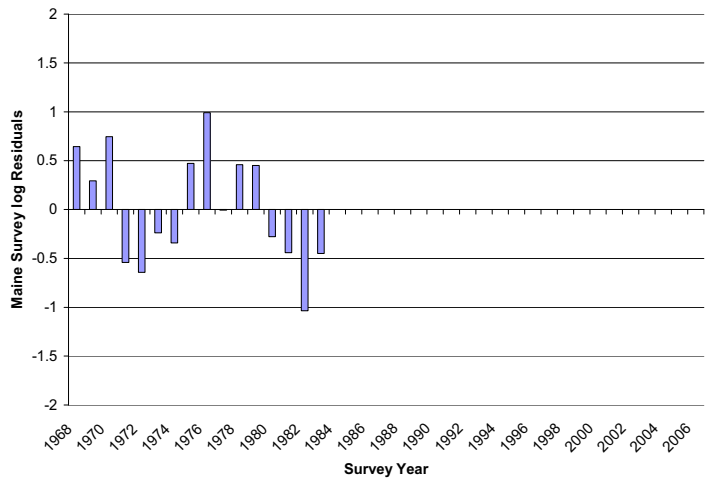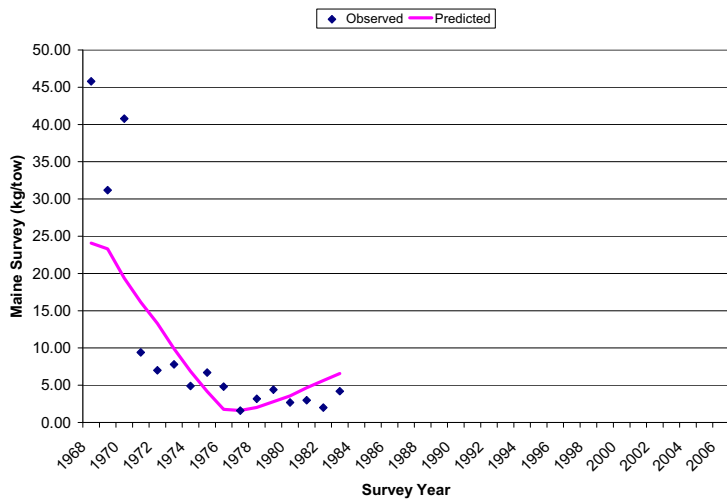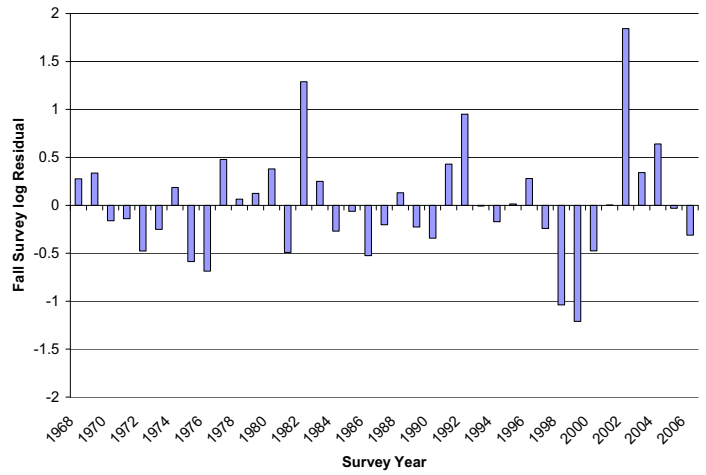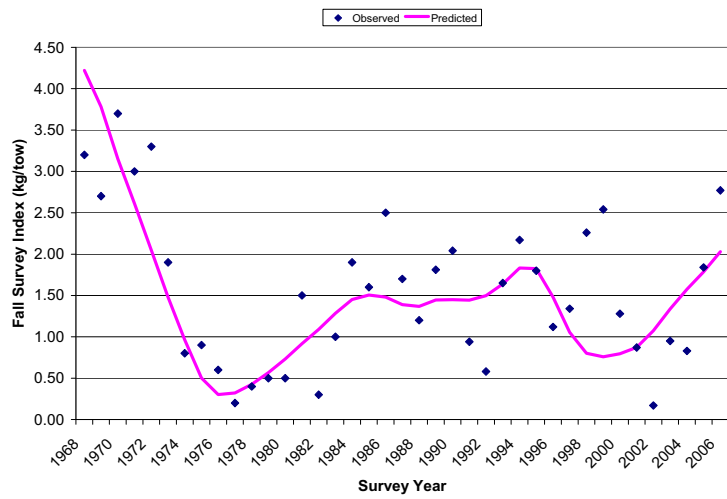Figure A6-9. Catch-Survey model (CSA) input data and results.

Figure A6-10. Observed survey index, predicted model fit and survey index log residuals from ASPIC analysis of Gulf of Maine northern shrimp biomass dynamics.
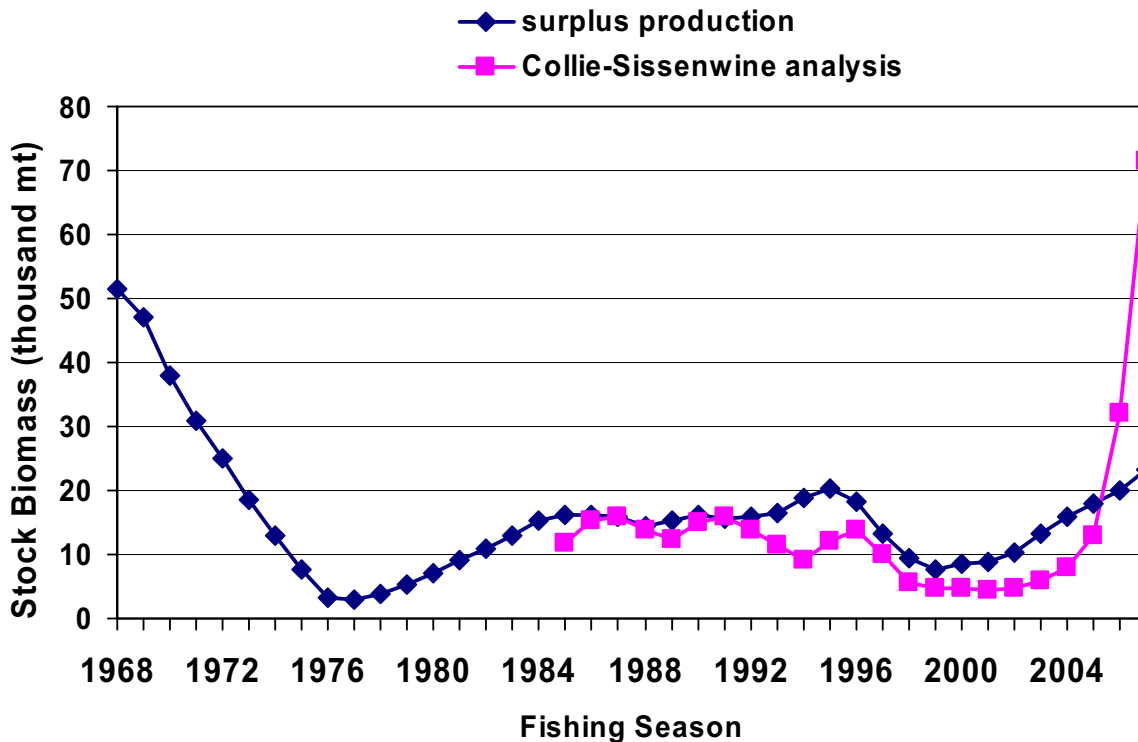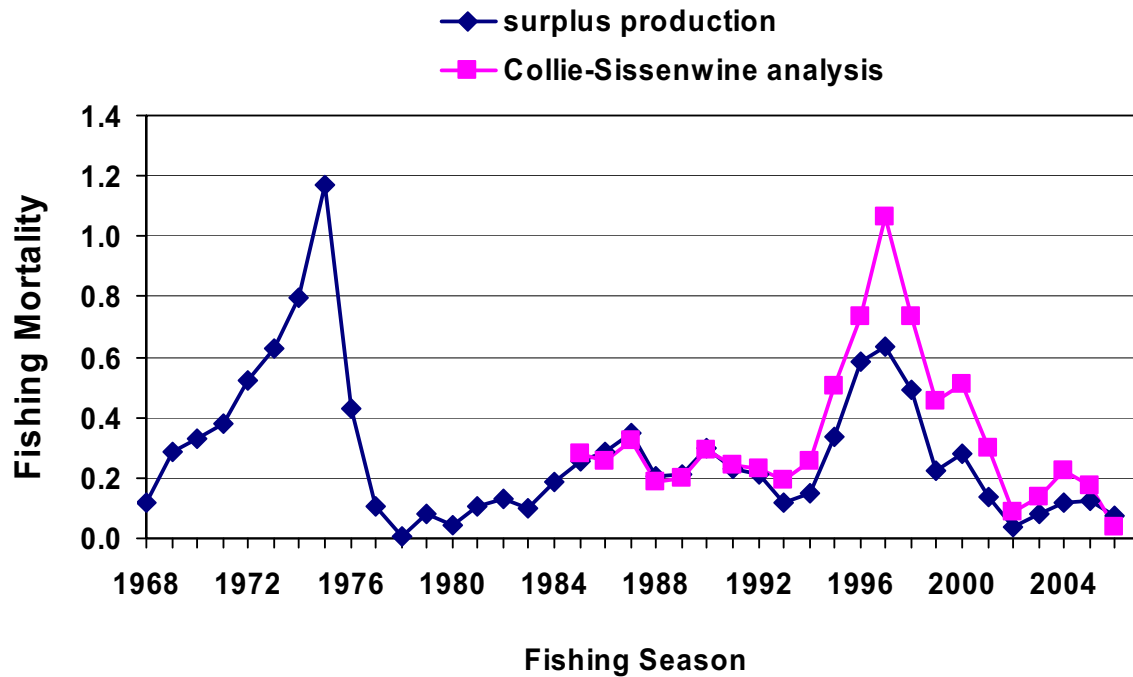
Figure A6-11. Estimates of fishing mortality (above) and stock biomass (below) for Gulf of Maine northern shrimp from CSA and surplus production (ASPIC) modeling.
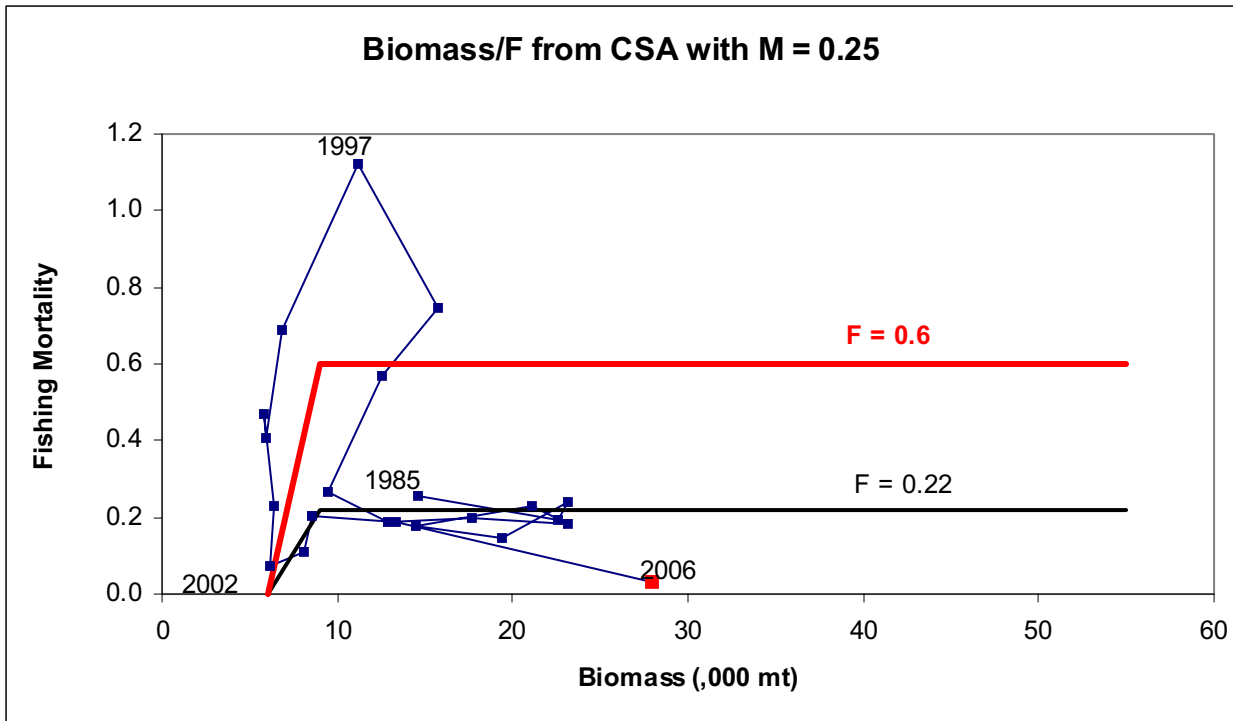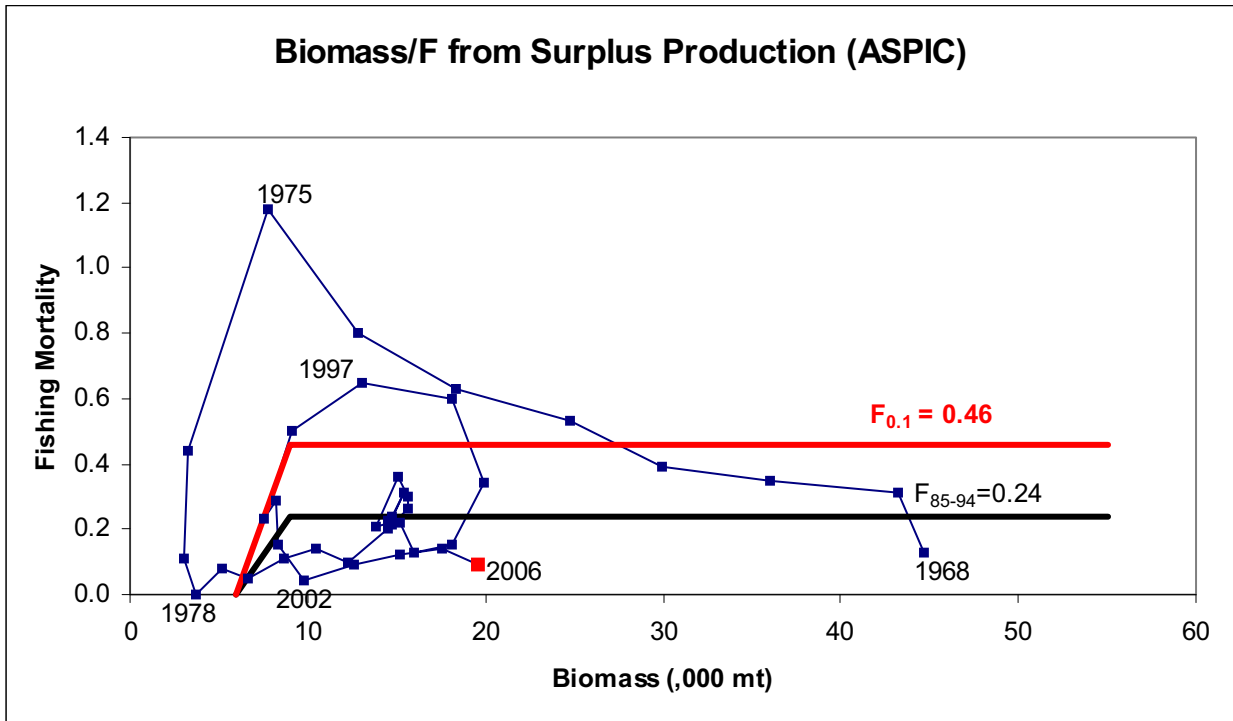
Figure A6-12. Biomass dynamics of the Gulf of Maine northern shrimp fishery, from surplus production (above) and Collie-Sissenwine (below) analyses, with fishing mortality and biomass reference points.
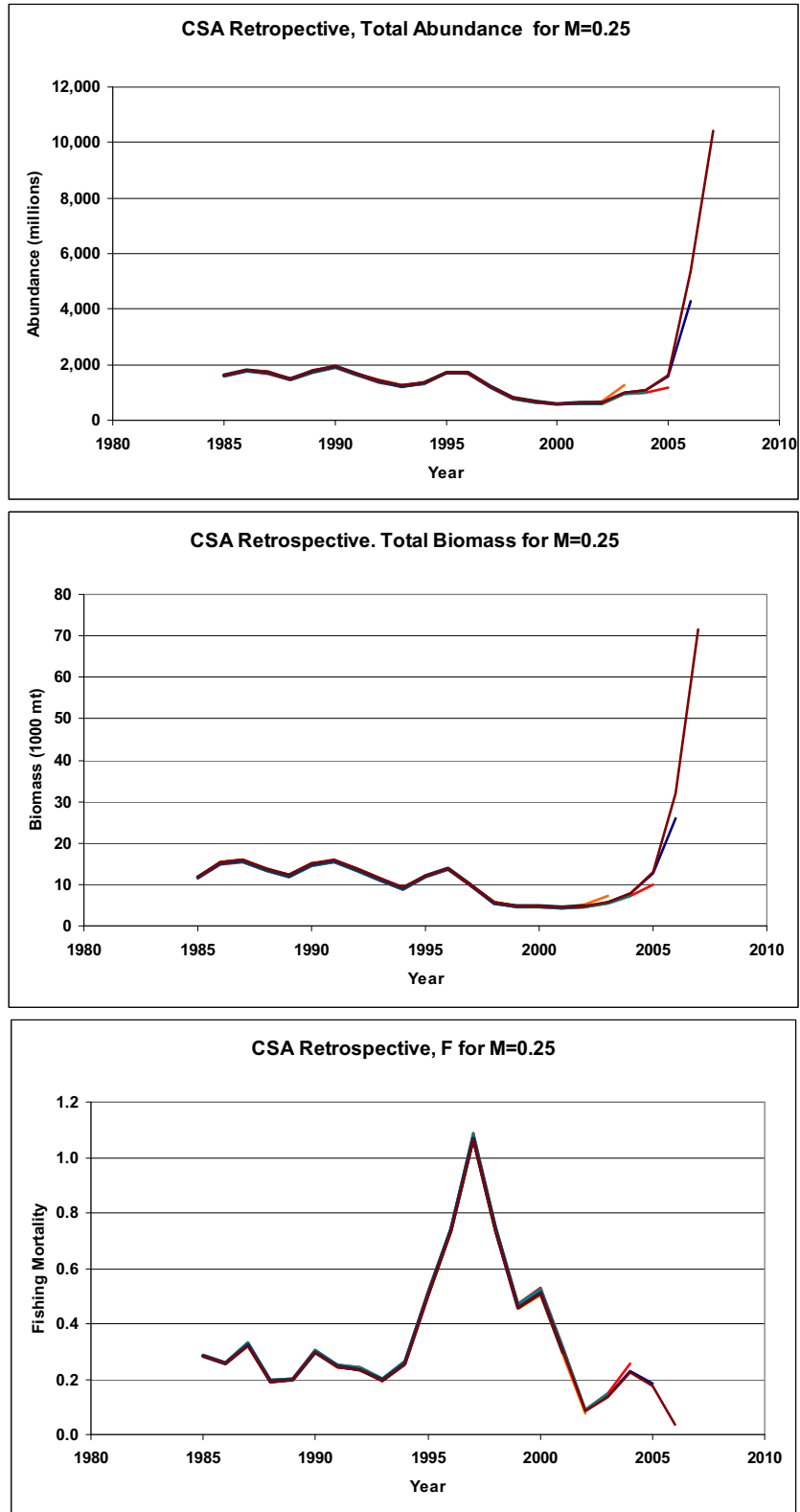
Figure A6-13. Retrospective CSA estimates of abundance (top), biomass (middle), and fishing mortality (bottom) for Gulf of Maine northern shrimp, with M=0.25.
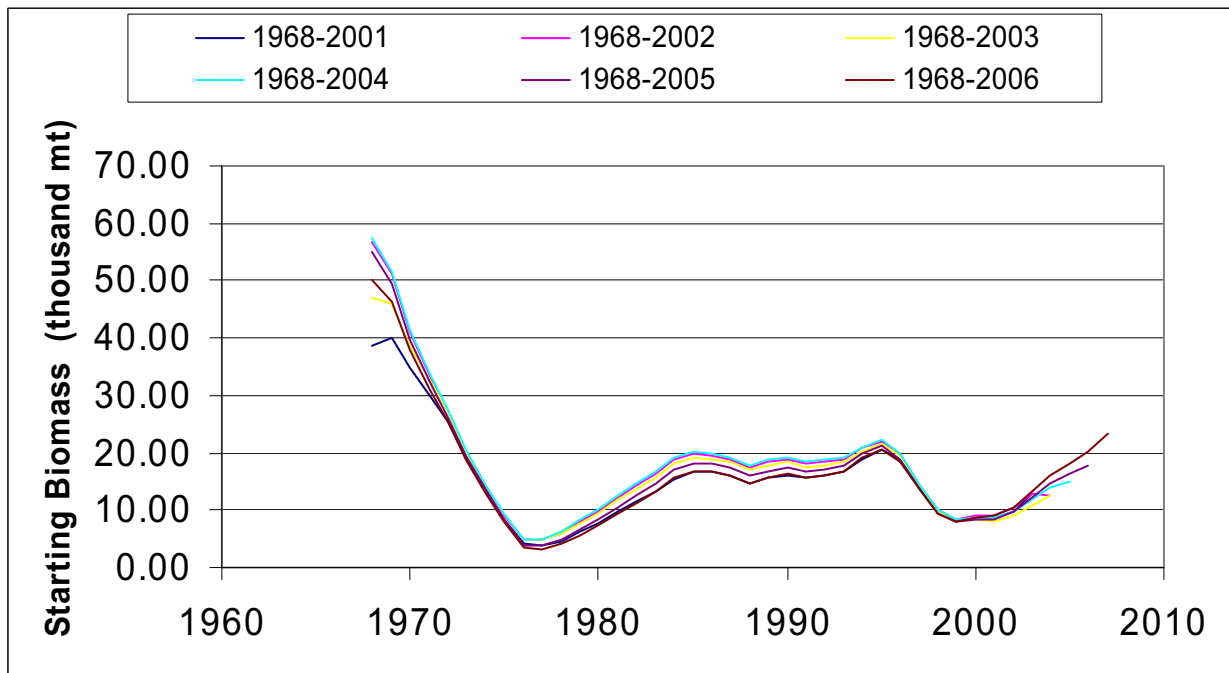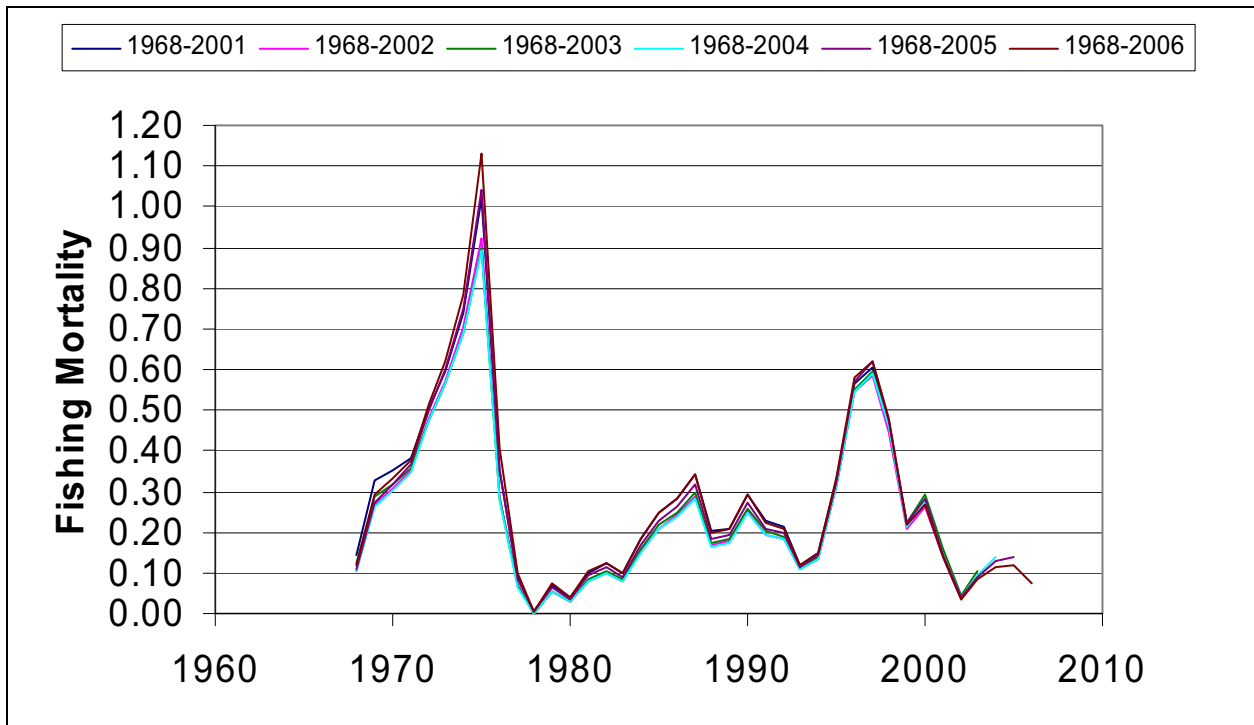
Figure A6-14. Retrospective surplus production estimates of fishing mortality (above) and biomass (below) for Gulf of Maine northern shrimp.
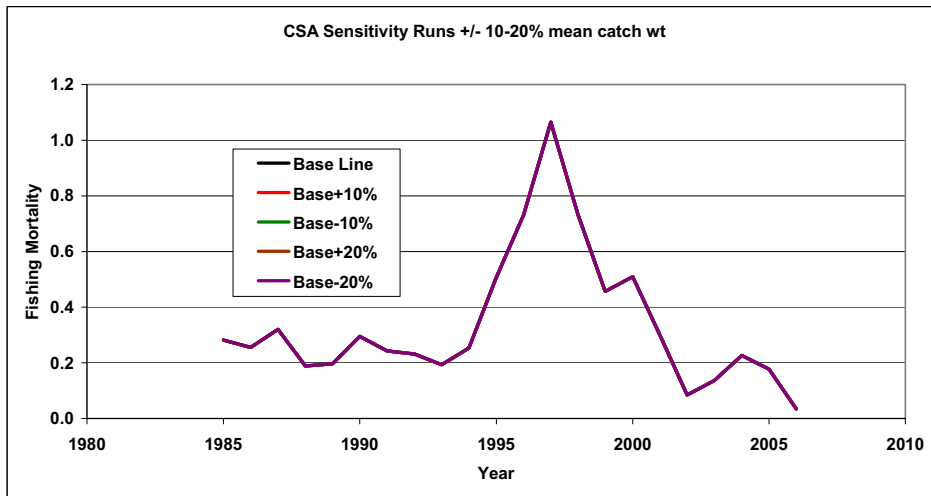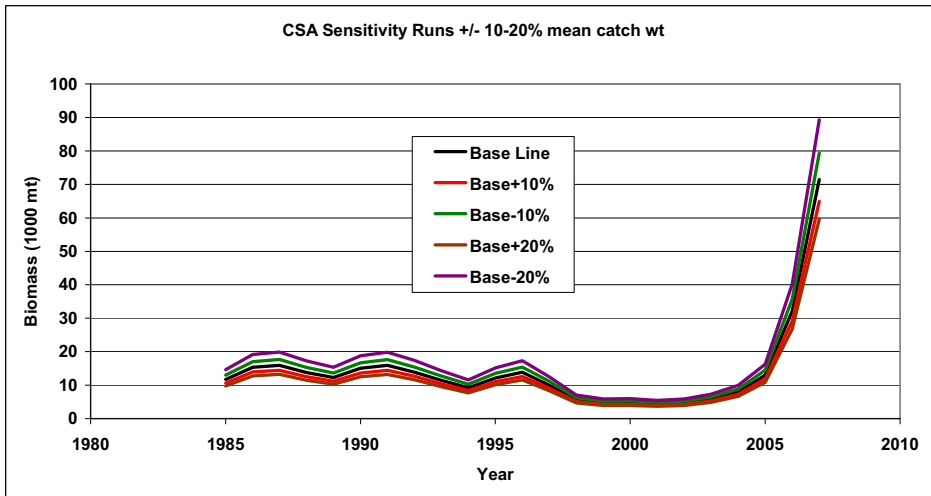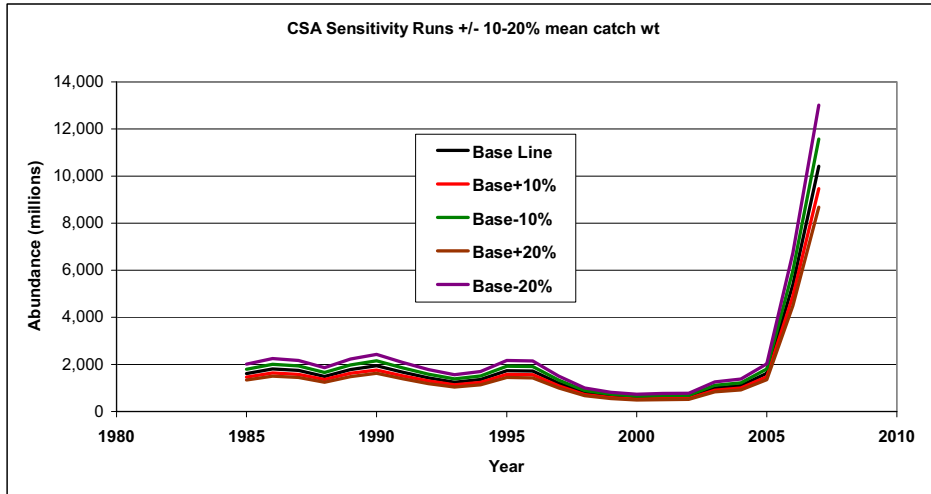
Figure A9-1.1. CSA abundance, biomass, and fishing mortality estimates when the mean weight of a landed shrimp is adjusted by +/- 10% or 20%.
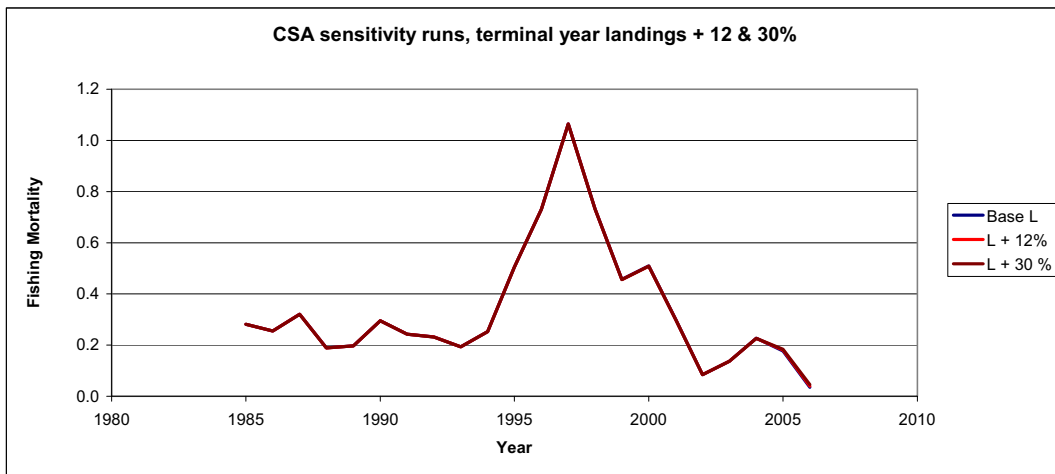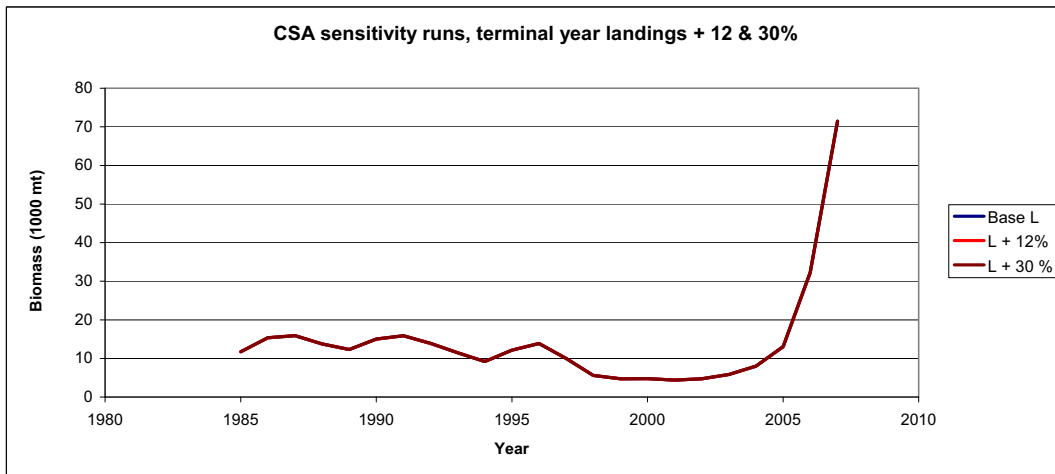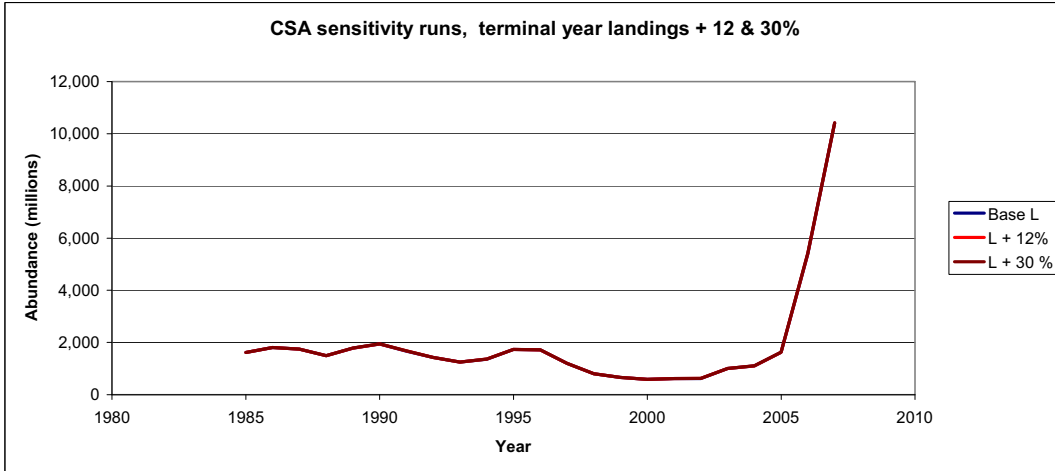
Figure A9-1.2. CSA abundance, biomass, and fishing mortality estimates when terminal year (2006) landings are adjusted by 12% and 30%, and 2005 landings are adjusted by 2%.
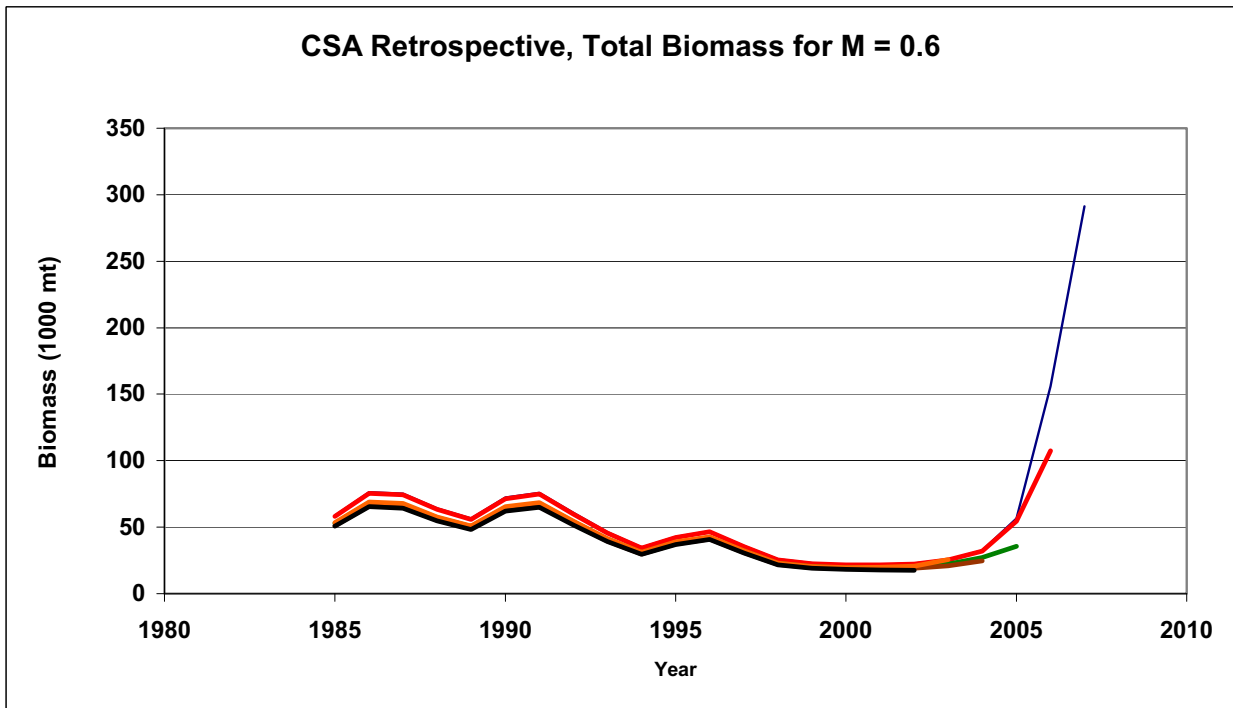
CSA Retrospective, Abundance for M = 0.6

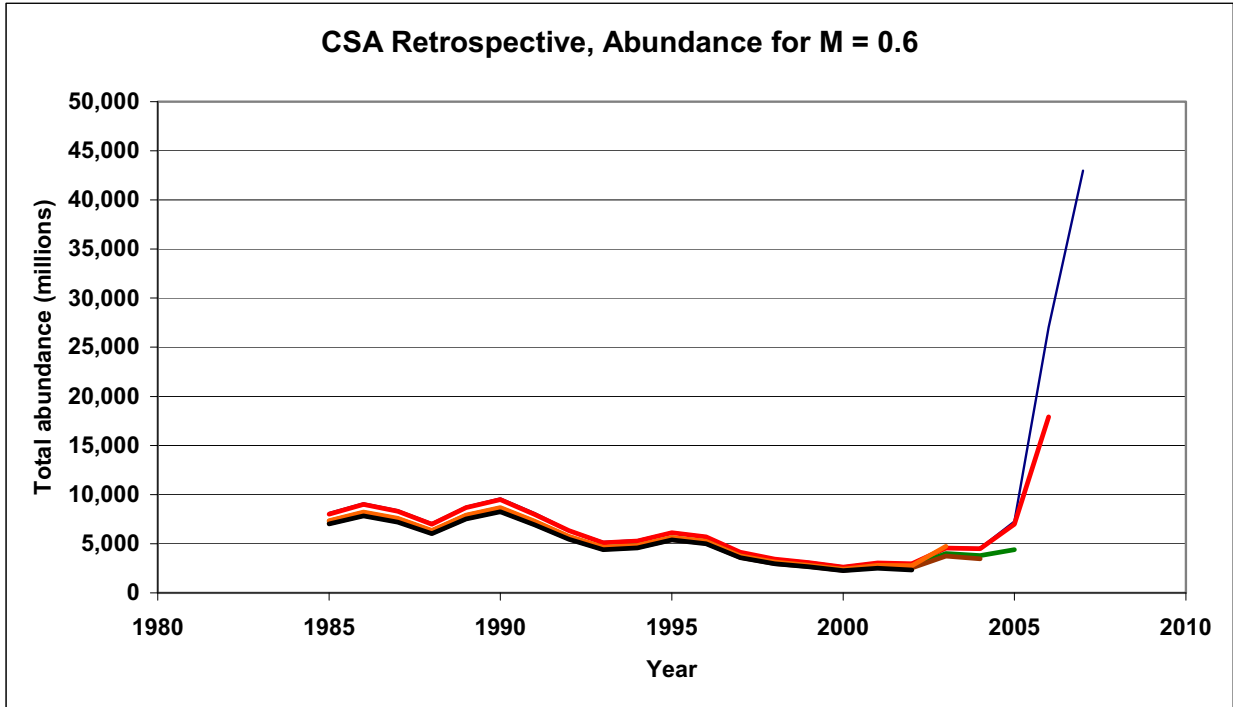**CSA Retrospective, Total Biomass for M = 0.6**

Figure A9-1.3. Retrospective CSA estimates of abundance (above) and biomass (below) for Gulf of Maine northern shrimp, with M=0.60.
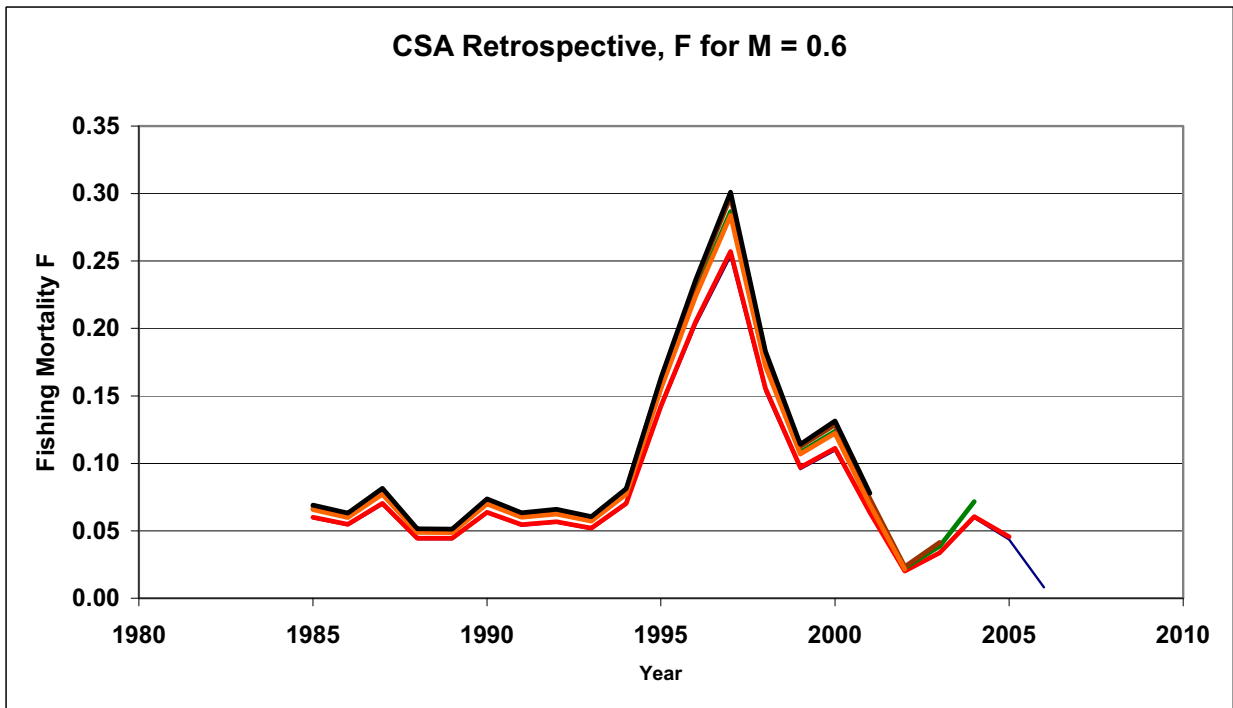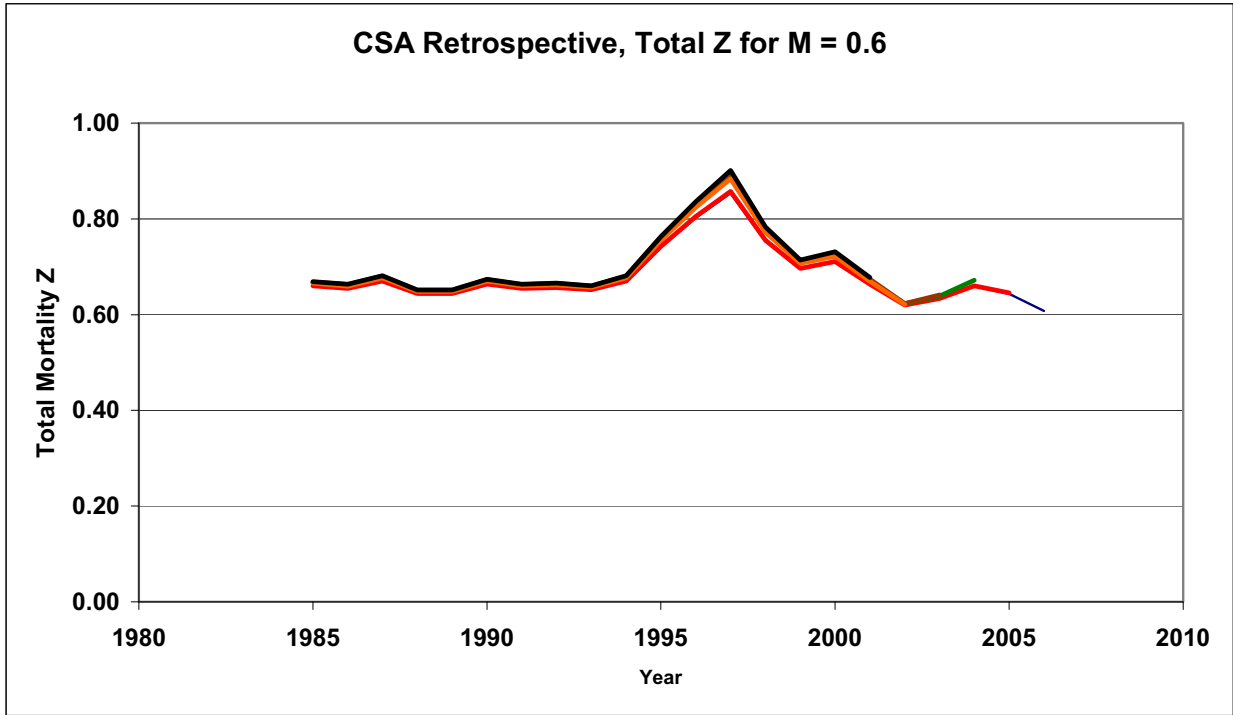
Figure A9-1.4. Retrospective CSA estimates of total mortality Z (above) and fishing mortality F (below) for Gulf of Maine northern shrimp, with M=0.60.
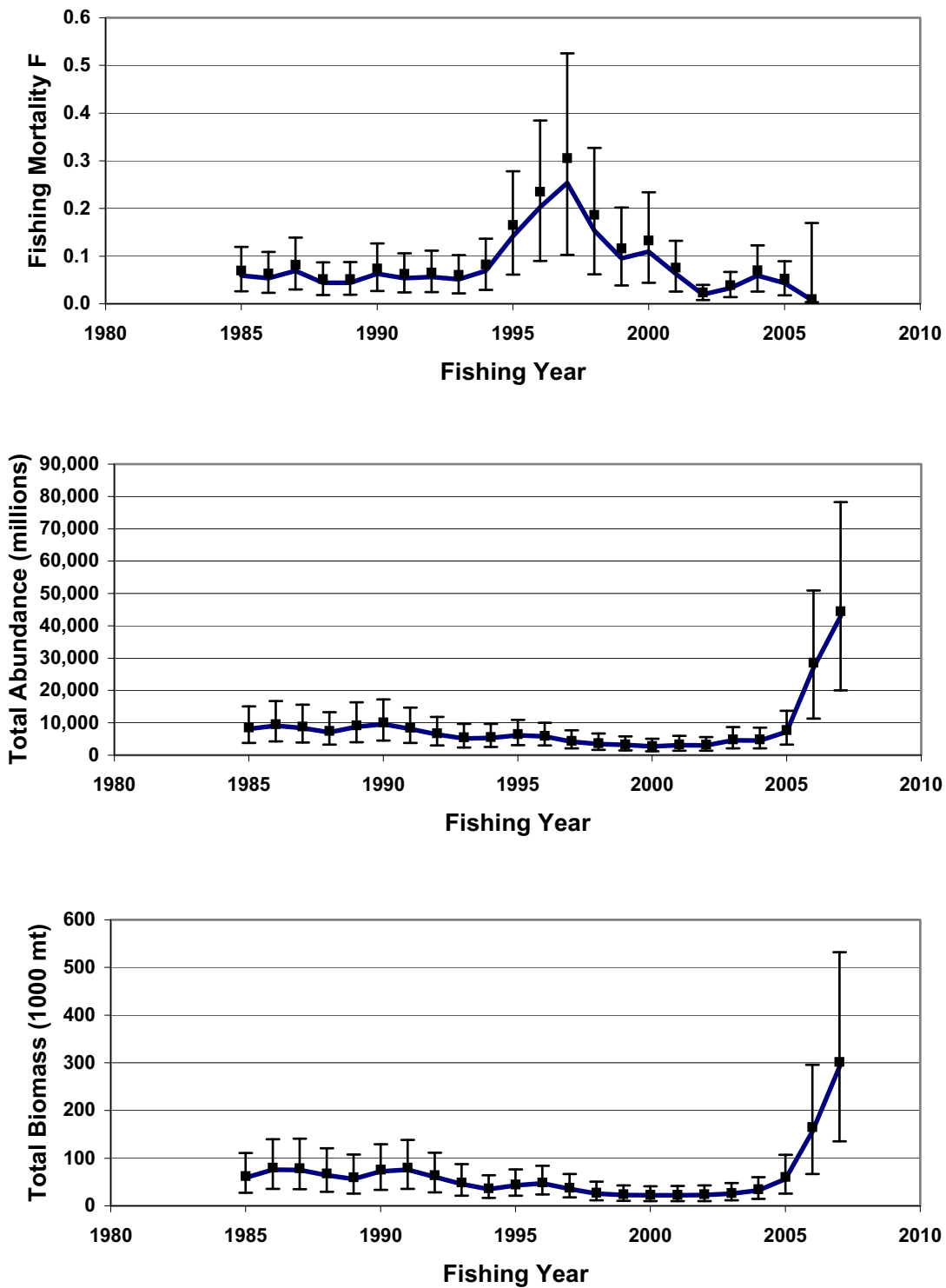
Figure A9-1.5. Fishing mortality, abundance, and biomass of Gulf of Maine northern shrimp as estimated by CSA, with least squares estimates, bootstrapped means (square symbols), and 80% confidence intervals. M=0.60.
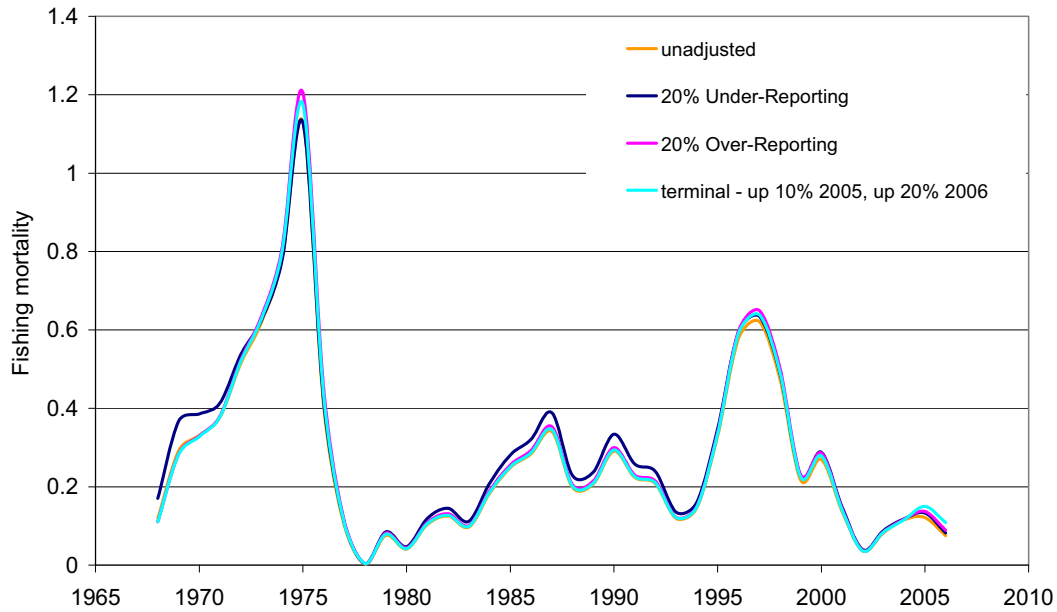
Figure A9-2.1. ASPIC fishing mortality estimates derived from unadjusted, 20% over-reported, 20% under-reported, and 10% and 20% terminal year biased commercial Northern shrimp landings.
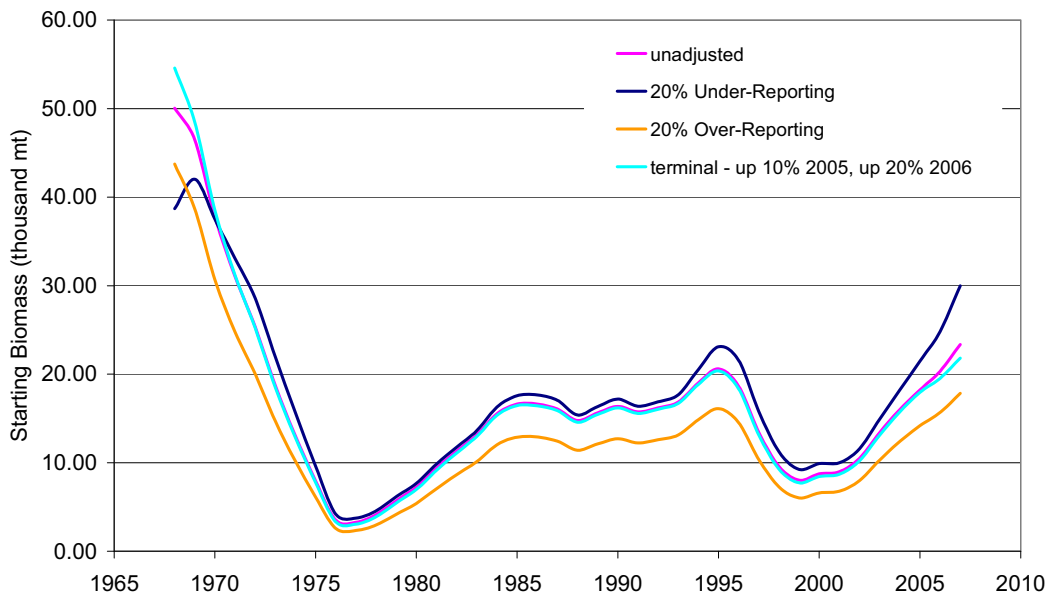

Figure A9-2.2. ASPIC starting biomass estimates derived from unadjusted, 20% over-reported, 20% under-reported, and 10% and 20% terminal year biased commercial northern shrimp landings.
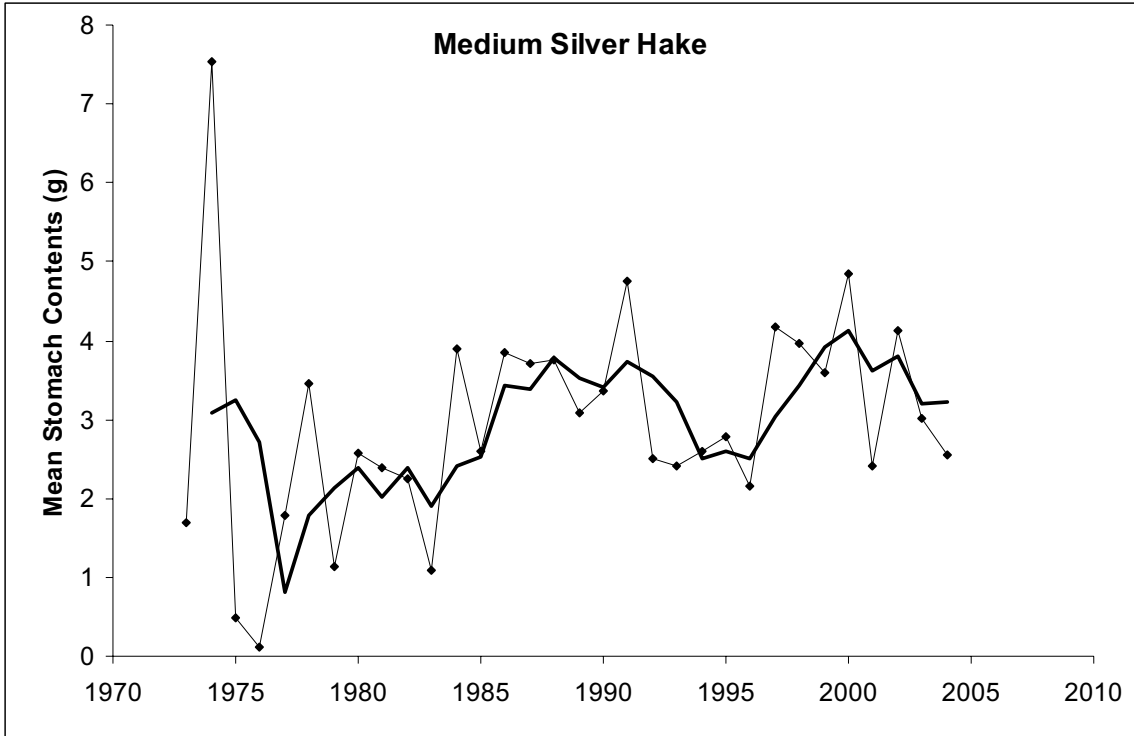
Figure A10-1a. Mean stomach contents of medium silver hake, fall season. The heavier line is the 3 year moving average.
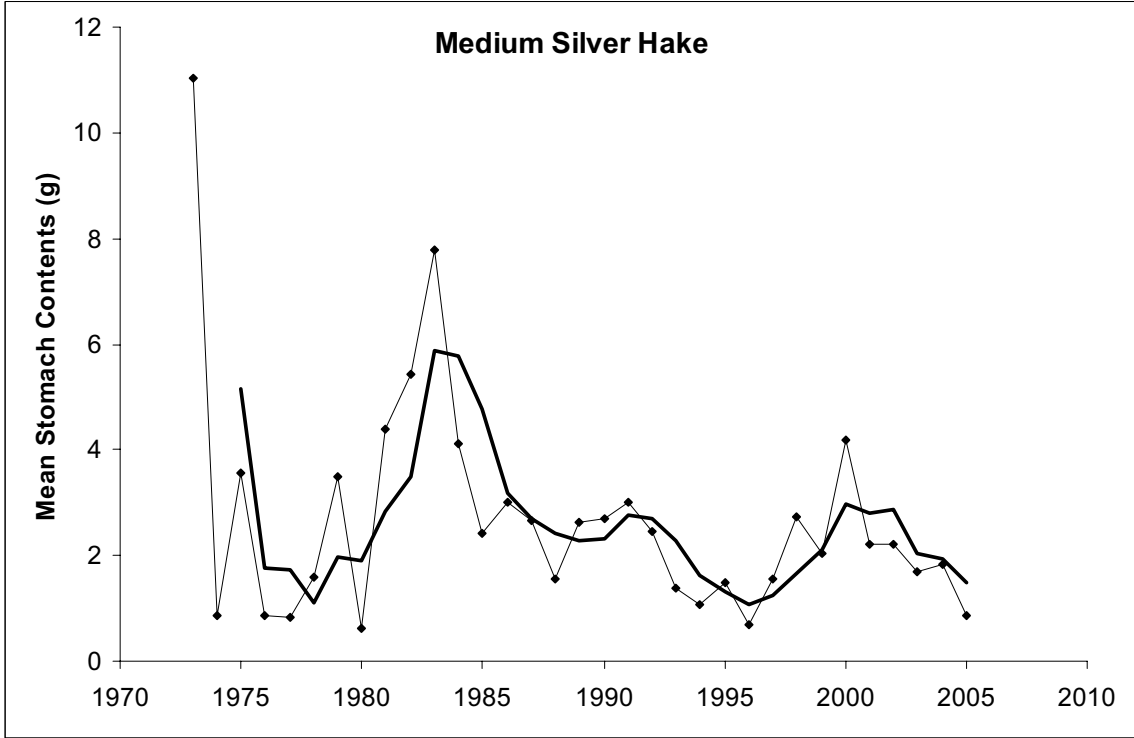

Figure A10-1b. Mean stomach contents of medium silver hake, spring season. The heavier line is the 3 year moving average.
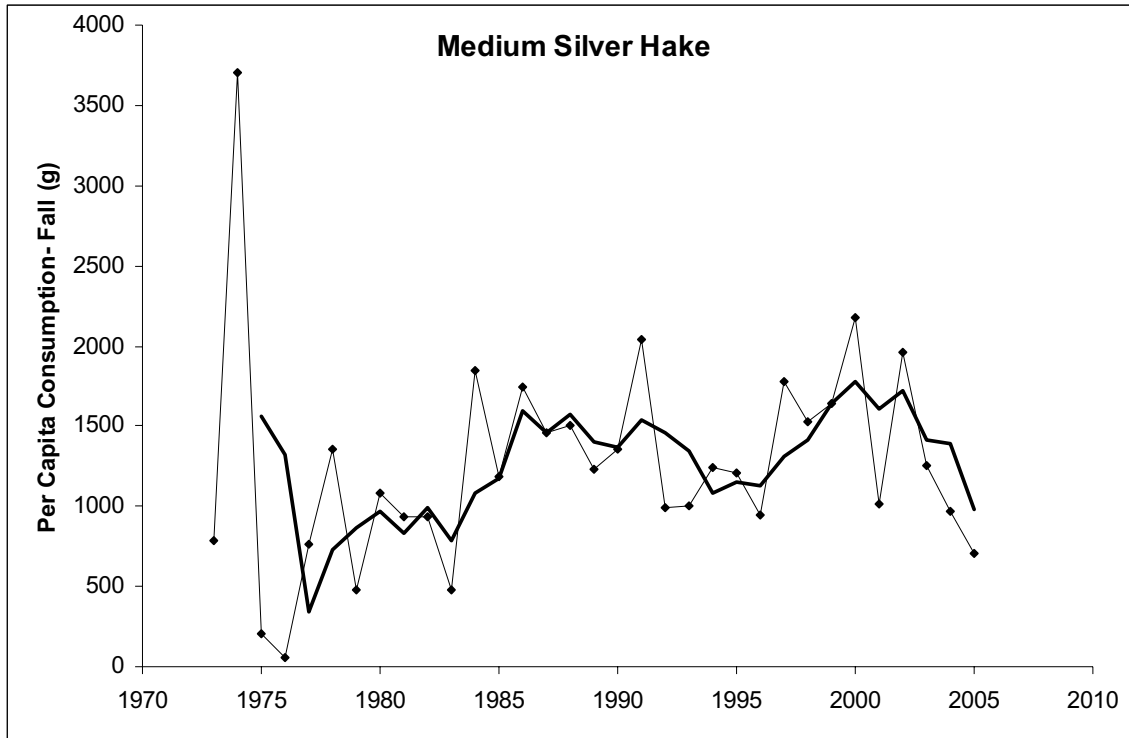
Figure A10-2a. Per capita consumption for medium silver hake, fall season. The heavier line is the 3 year moving average.
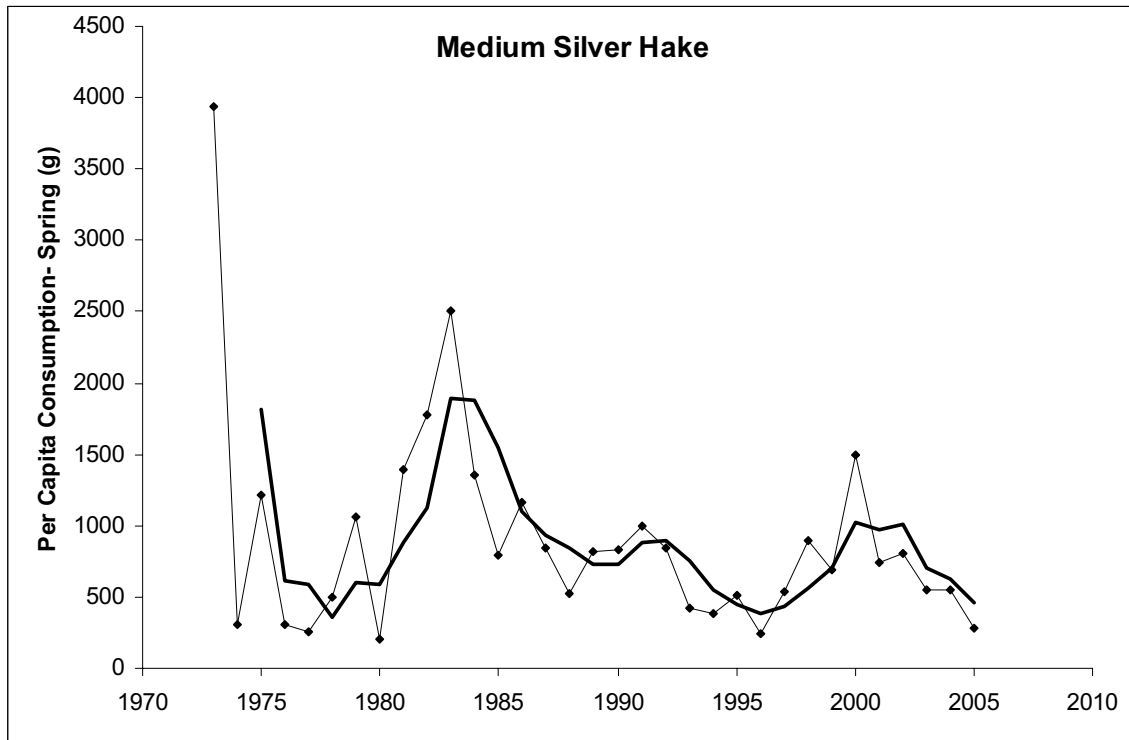

Figure A10-2b. Per capita consumption for medium silver hake, spring season. The heavier line is the 3 year moving average.
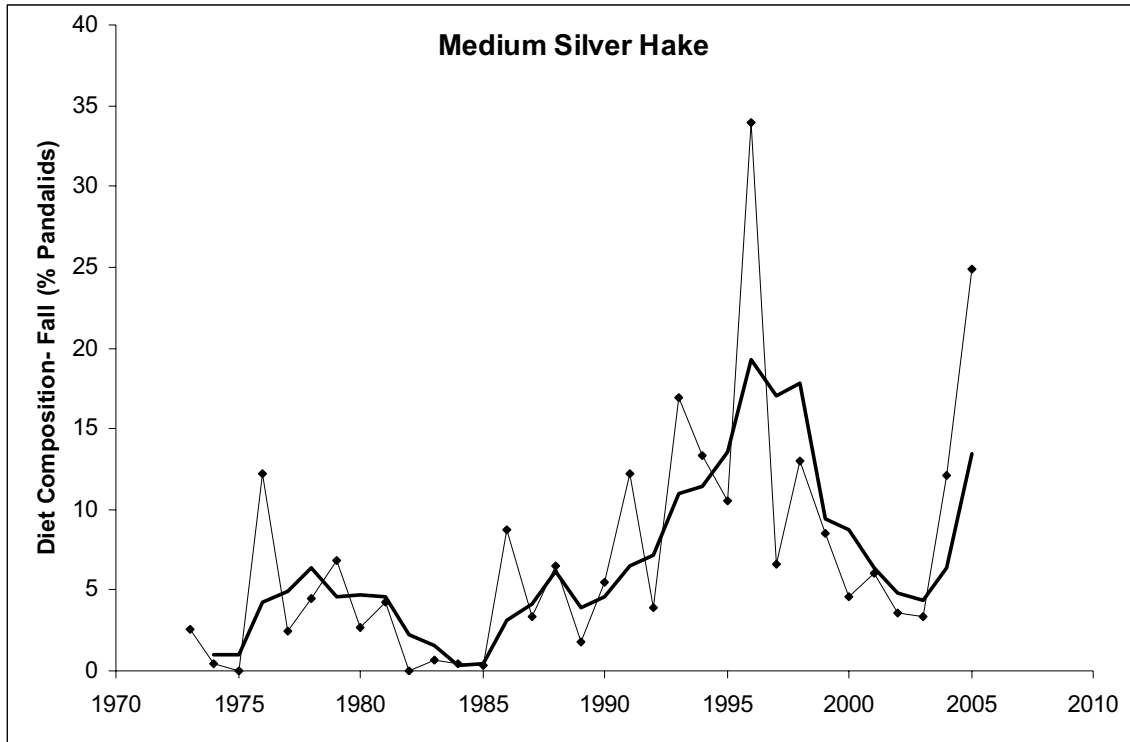
Figure A10-3a. Diet composition of pandalids in medium silver hake, fall season. The heavier line is the 3 year moving average.
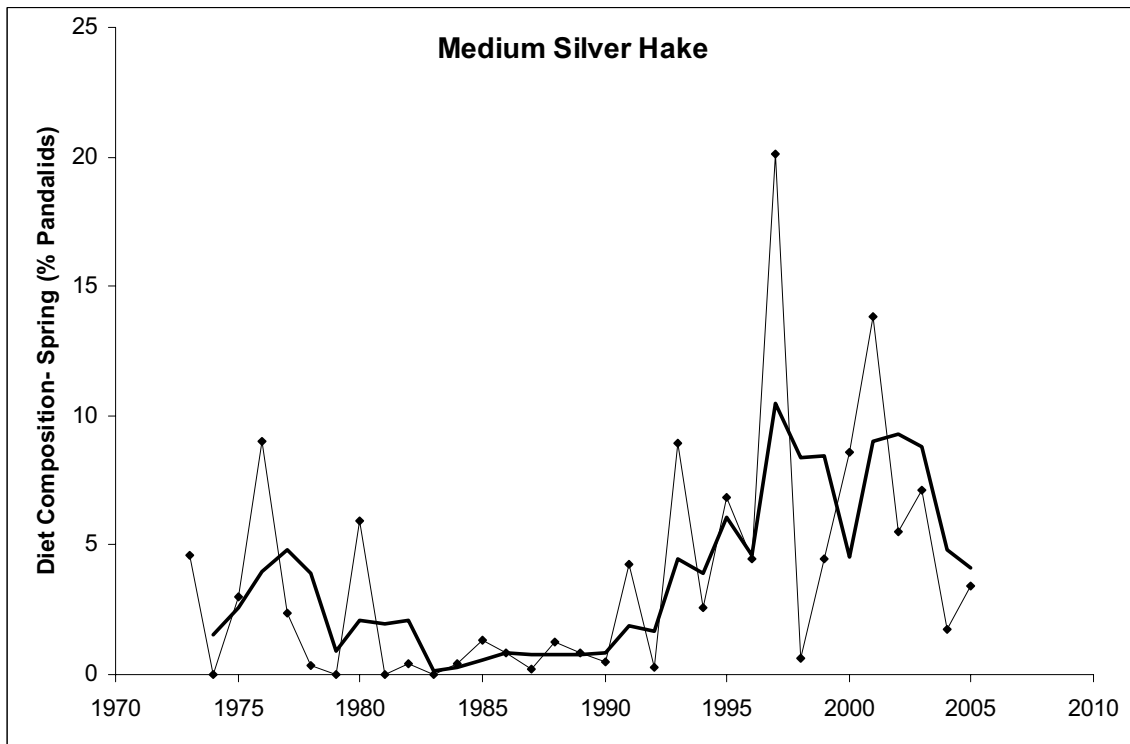

Figure A10-3b. Diet composition of pandalids in medium silver hake, spring season. The heavier line is the 3 year moving average.
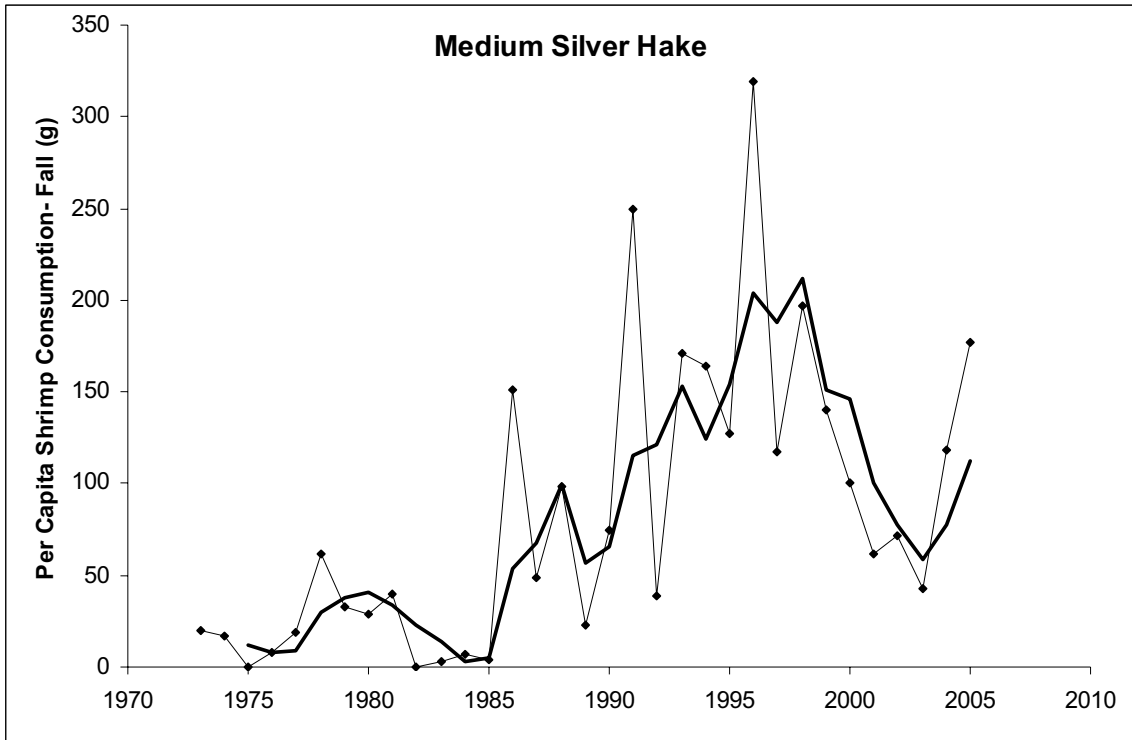
Figure A10-4a. Per capita consumption of pandalid shrimp by medium silver hake, fall season. The heavier line is the 3 year moving average.
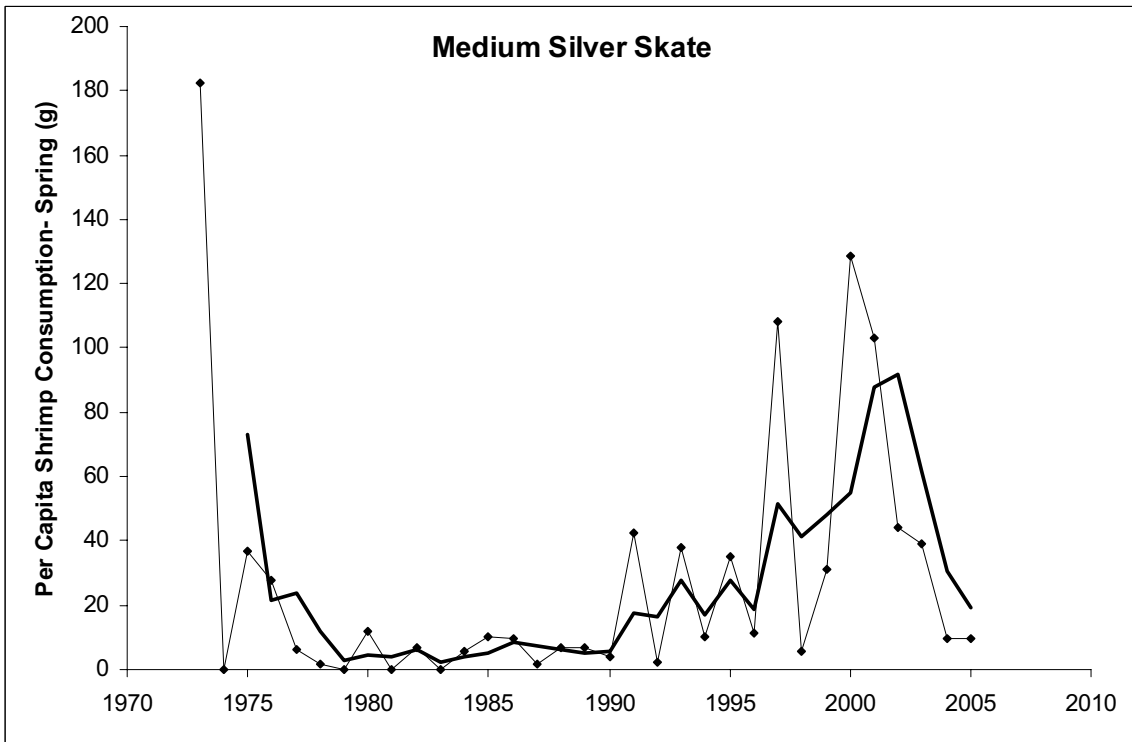

Figure A10-4b. Per capita consumption of pandalid shrimp by medium silver hake, spring season. The heavier line is the 3 year moving average.
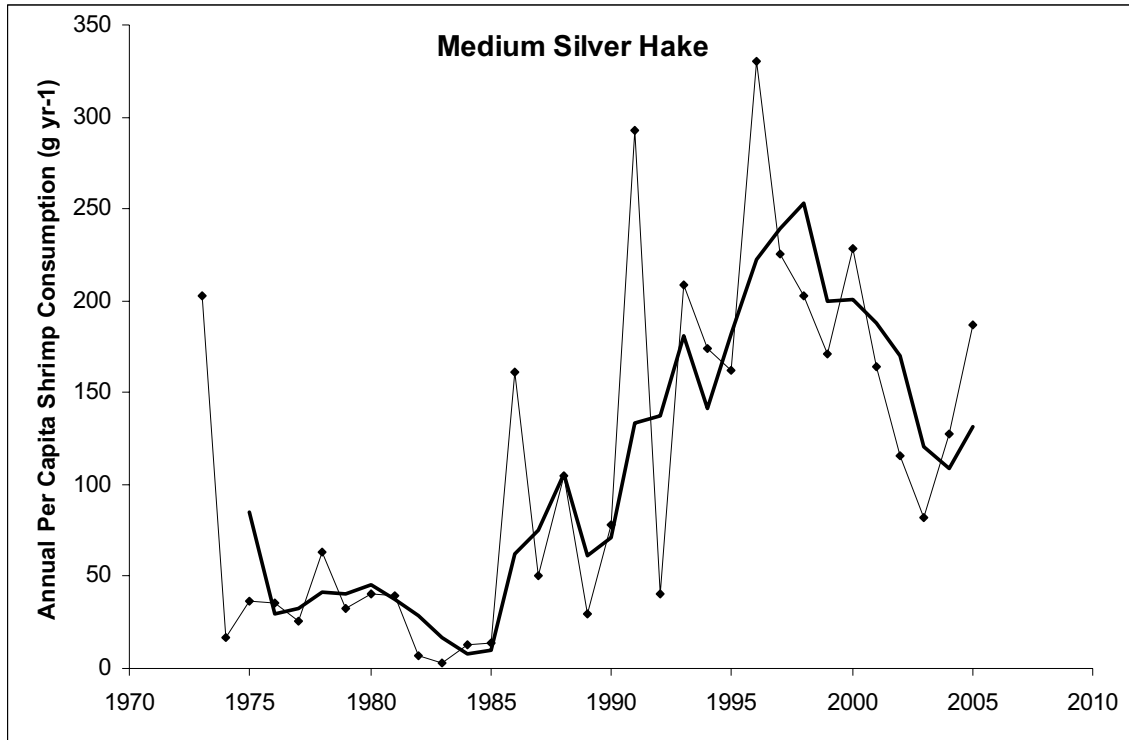
Figure A10-5. Annual per capita consumtion of pandalid shrimp by medium silver hake. The heavier line is the 3 year moving average.
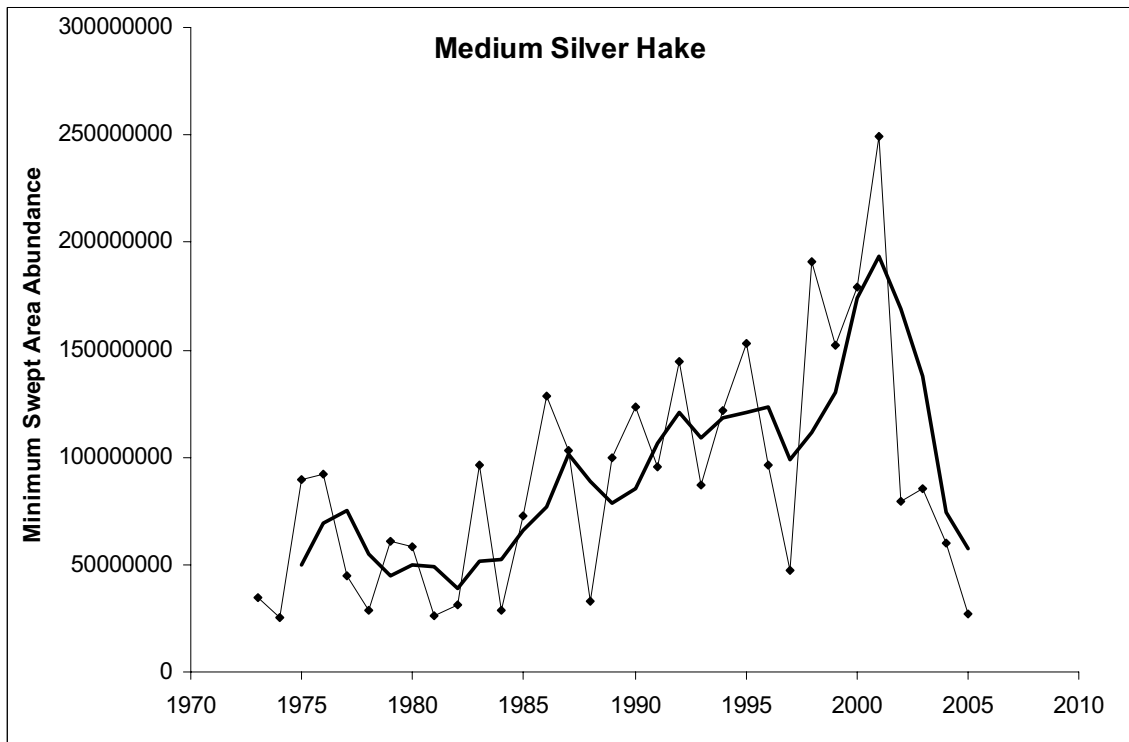

Figure A10-6. Minimum swept-area abundance of medium silver hake estimated from bottom trawl surveys. The heavier line is the 3 year moving average.
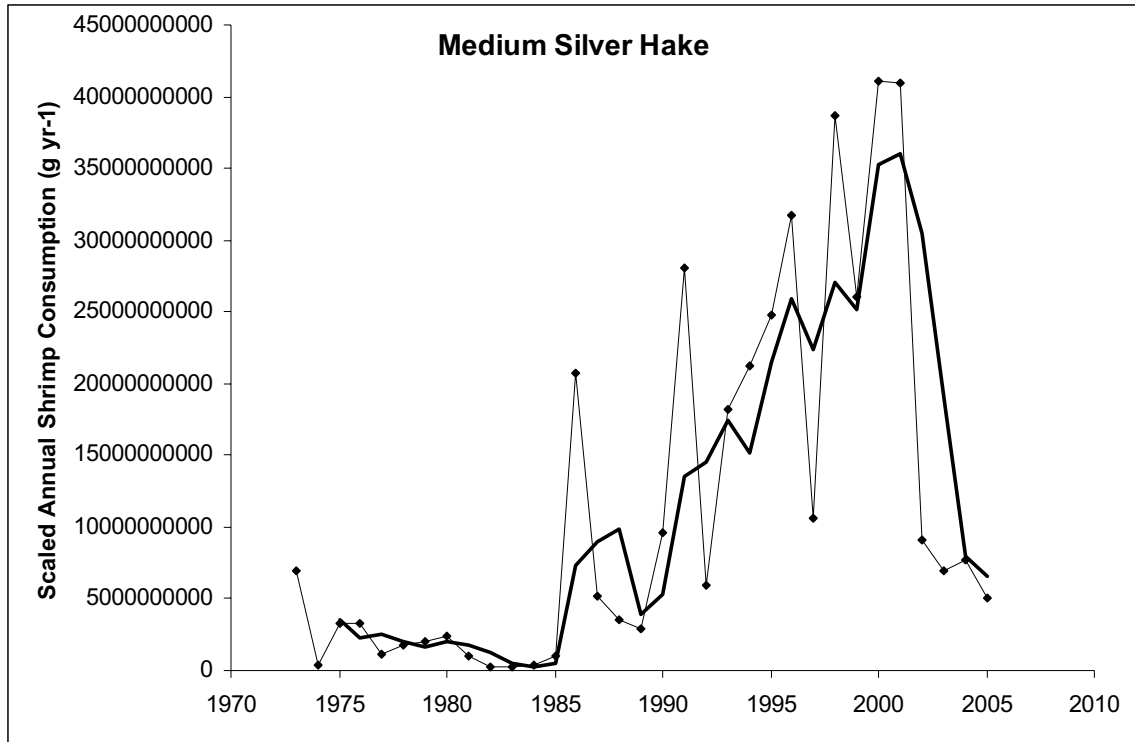
Figure A10-7. Total biomass of pandalid shrimp removed via consumption by medium silver hake. The heavier line is the 3 year moving average.
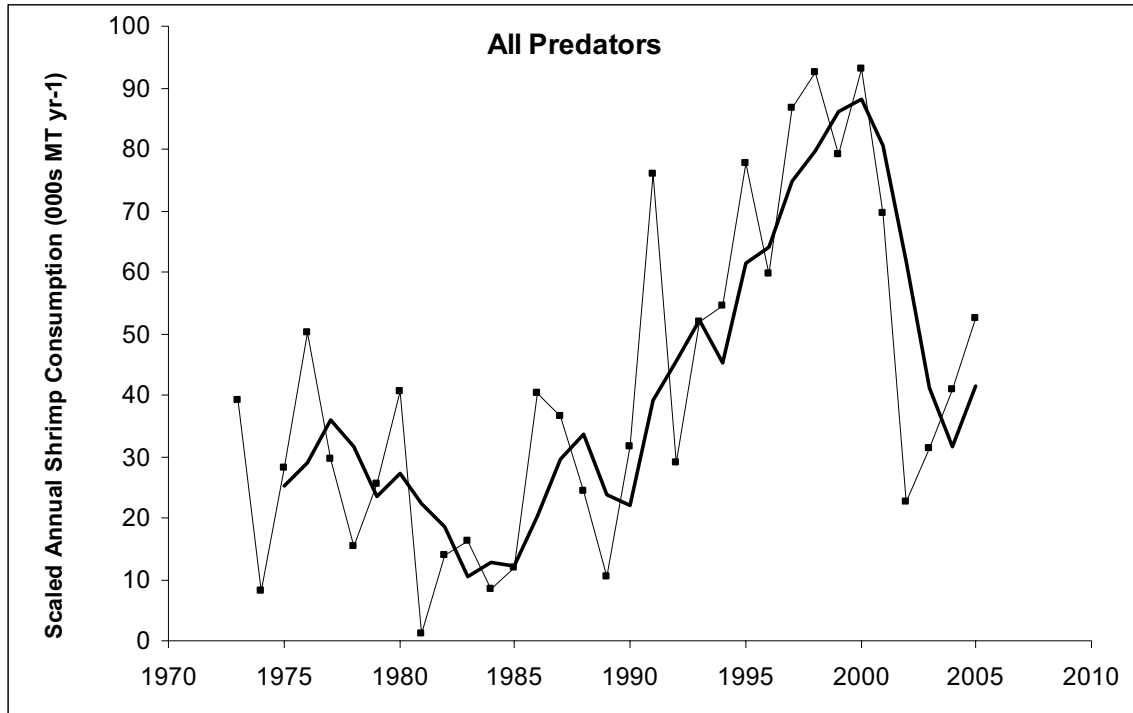
Figure A10-8a. Total pandalid shrimp biomass consumed by all predators. The heavier line is the 3 year moving average.
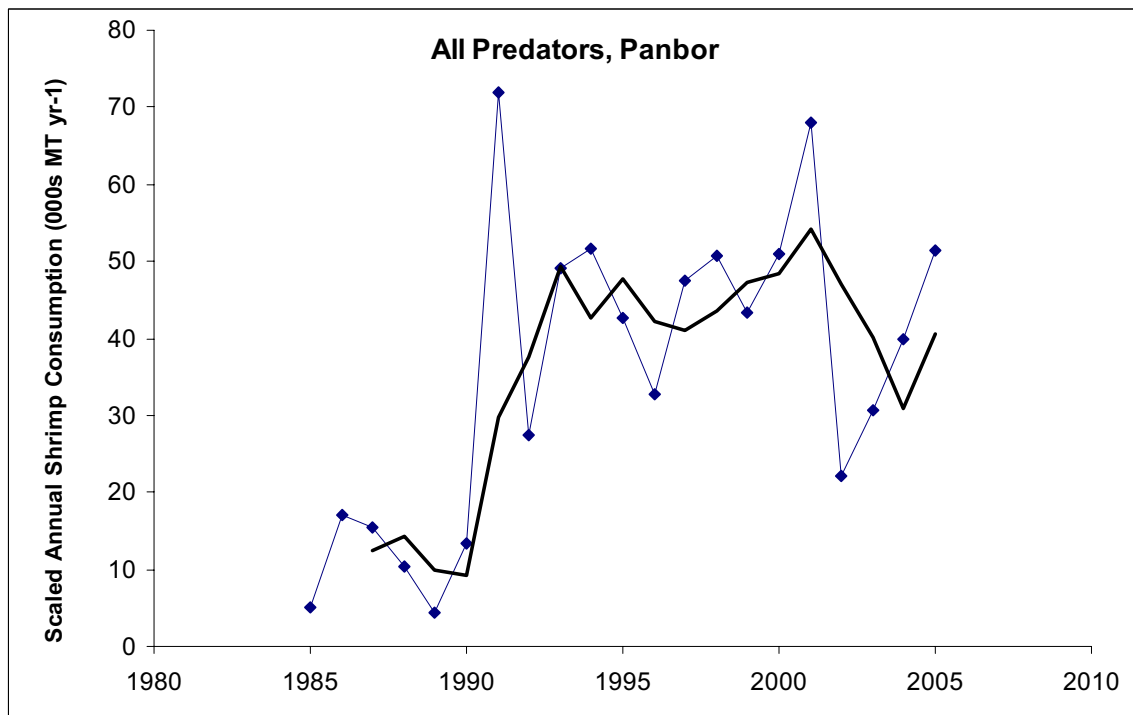

Figure A10-8b. Total *Pandalus borealis* shrimp biomass consumed by all predators. The heavier line is the 3 year moving average.
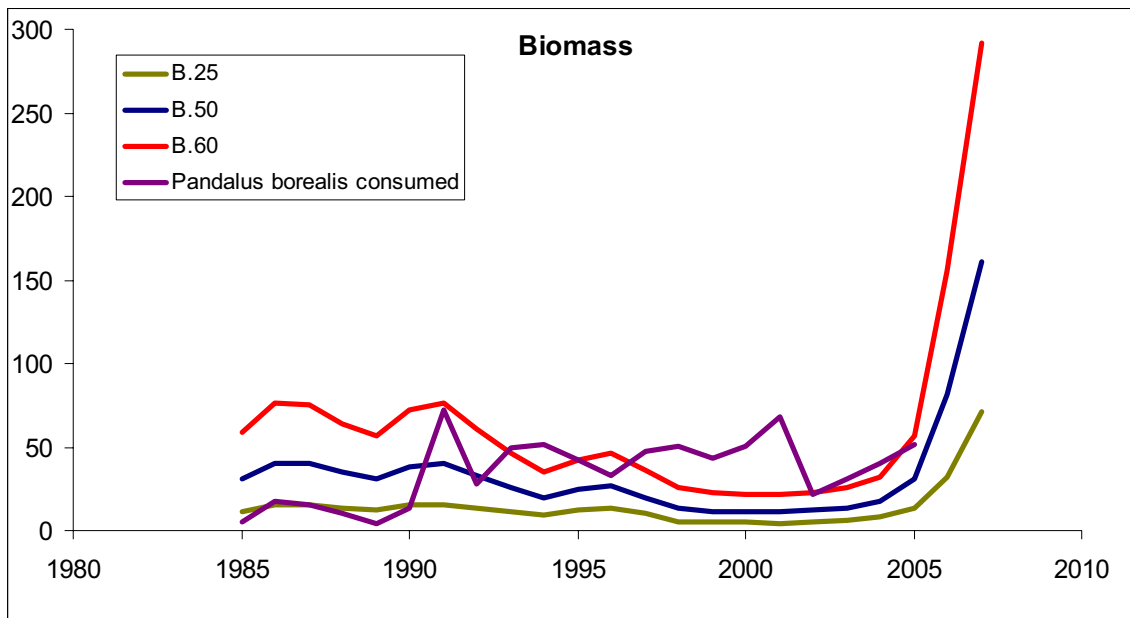
Figure A10-9a. Comparison of total *Pandalus borealis* shrimp biomass consumed by all predators compared to CSA models with different levels of natural mortality.
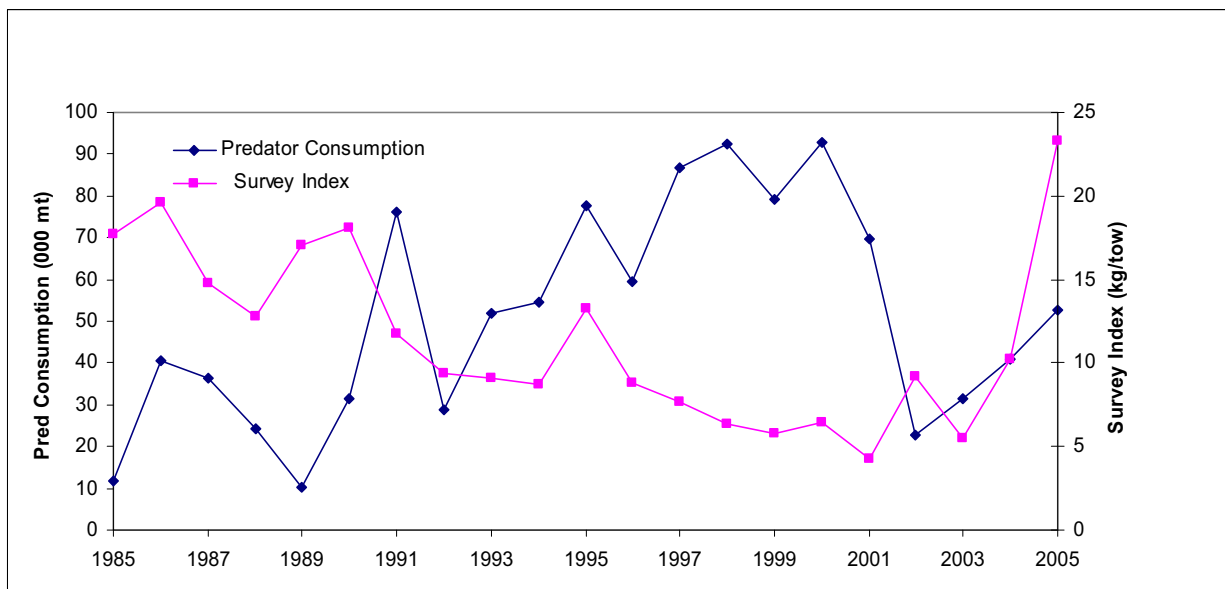

Figure A10-9b. Comparison of total *Pandalus borealis* shrimp biomass consumed by all predators compared to shrimp summer survey biomass index.