C. POLLOCK ASSESSMENT SUMMARY FOR 2010

State of Stock

Comparing the current 2009 estimates of spawning stock biomass (SSB) and fishing mortality rate (F) to the newly accepted reference points, the pollock stock is not overfished and overfishing is not occurring. A new assessment model (ASAP) is accepted as the best scientific information available for determining stock status for pollock (*Pollachius virens*). SSB in 2009 is estimated to be 196,000 mt and the average F on ages 5-7 (F_{5-7}) is estimated to be 0.07 (Figure C3 and Figure C8).

$F_{40\%}$ is recommended as the new proxy for F_{MSY} (the overfishing threshold). The average fishing mortality on ages 5 to 7 is chosen as the basis of indicator and reference point estimation in order to account for temporal changes in fishery age-specific selectivity.

$F_{40\%}$, measured as F on the fully selected age (age-7) in the most recent period (2005 – 2009) is 0.41, which is equivalent to an average fishing mortality on ages 5-7 (F_{5-7}) of 0.25.

SSB_{MSY} (the biomass target) is calculated from projections at $F_{40\%}$ and is estimated to be 91,000 mt.

If the previously used AIM model had been used to determine stock status, the resource would have been judged to be overfished and overfishing to be occurring. In contrast to the previously used AIM model, ASAP uses age structure, additional surveys, more comprehensive catch information, changes in selectivity and uncertainty in the input data (see Special Comments).

Projections

The ASAP model estimates that the stock is not overfished, so no rebuilding projections were conducted. For the purposes of informing ABC decisions, projections were made for three constant F scenarios: $F=F_{statusquo}=F_{2009}$, $F=0.75*F_{40\%}$, and $F=F_{40\%}$. Under all three scenarios (Table C1a), spawning biomass declines from SSB_{2009}=196,000 mt until it approaches equilibrium at the projected F. Under $F_{40\%}$ the median SSB equilibrates at 91,000 mt (the proxy for SSB_{MSY}). Projected median recruitment does not vary by F scenario, because the same time series of recruitments (1970-2007) was resampled in all projections. The median recruitment was 19.3 million age 1 fish, with 5th and 95th percentiles ranging from 8.4 to 42 million fish.

Projected median catch (which includes both commercial and recreational fleets) under $F_{status-quo}$ decreases from 8,100 mt in 2010 to 7,200 mt in 2012, then gradually increases until equilibrating around 8,400 mt in 2017 (Table C1b). Projecting at $0.75*F_{40\%}$, the median catch fluctuates from 19,800 mt in 2010 to 15,400 mt in 2012, and continues to oscillate in this range until equilibrating at 14,500 mt. Projecting at $F_{40\%}$, median catch declines from 25,700 mt in 2010 to 17,500 mt in 2017 with minor fluctuations until equilibrating at 16,200 mt (the proxy for MSY). Note that a projected 2010 catch of 25,700 mt would exceed MSY, be more than double recent catch, and has not been observed since the 1980s.

Catch and Status Table: Pollock in US Waters of Areas 5&6

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Min	Max	Mean
Comm Lands (mt)	4043	4109	3580	4794	5070	6509	6067	8372	9965	7477	2962	24994	10723
Comm Disc (mt)	117	73	68	45	103	100	69	147	362	362	45	473	164
Rec Lands (mt)	243	471	547	499	669	520	571	533	941	468	50	941	355
Rec Disc (mt)	356	875	613	472	241	272	252	227	926	428	34	926	327
Total Catch (mt)	4759	5528	4808	5810	6083	7401	6959	9278	12194	8735	3754	25170	11920
SSB (000s mt)	130	148	166	199	214	222	236	224	227	196	69	327	176
Exploitable Biomass (000s mt)	74	87	95	114	113	133	138	125	105	86	37	168	92
Ave F on ages 5-7	0.062	0.061	0.047	0.047	0.037	0.038	0.034	0.051	0.082	0.070	0.034	0.486	0.157
Full F	0.073	0.072	0.057	0.057	0.060	0.062	0.057	0.084	0.134	0.117	0.057	0.508	0.177
Recr (000s)	50260	22385	34708	13792	18057	11891	13982	16355	20812	20804	7244	57510	21360

[1]The value for commercial discards in 2009 was assumed to be equal to the value in 2008.
[2]Recreational discards were calculated assuming 100% discard mortality.

Stock Distribution and Identification

Pollock move widely throughout the Gulf of Maine and into Canadian waters. Previous assessments of pollock assumed a variety of stock definitions. Recent assessments of pollock in US waters are for "the portion of the unit stock of pollock primarily within the USA EEZ (NAFO Subareas 5&6) including a portion of eastern Georges Bank (Subdivision 5Zc) that is under Canadian management jurisdiction". Canadian stock assessments treat the management unit within the Canadian EEZ separately. Given uncertainties in stock structure and management implications, a refined assessment unit that reflects US jurisdictional waters was used (see Special Comments).

Catches

Pollock were traditionally landed as bycatch in various demersal otter trawl fisheries, but directed otter trawl effort increased during the 1980s, peaking in 1986 and 1987. Directed effort by US trawlers declined in the 1990s and early 2000's, but there have been recent increases in landings that may reflect increased targeting of pollock (Figure C1). Similar trends have also occurred in the U.S. winter gillnet fishery.

U.S. commercial landings increased from approximately 4,000 mt per year in the late 1960s to a peak of 24,000 mt in 1986. Landings rapidly decreased to 4,000 mt in 1996, and generally increased to 10,000 mt in 2008. Historical landings were primarily from trawl fisheries, but contributions from gillnet fisheries generally increased, and the recent fishery is composed of 60% trawl and 40% gillnet landings.

Commercial discards were estimated for 1989 to 2008 (data were not available for 2009, so an assumed value equal to 2008 discards was used). Discards were assumed to be negligible prior to 1989. Discard estimates ranged from 1% to 8% of US commercial landings, with an average of 3% for all years. The four fleets that account for nearly all pollock discards were small-mesh otter trawl, large-mesh otter trawl, large-mesh gillnet, and extra-large mesh gillnet.

Recreational catch is highly variable from year to year. Recreational catch peaked at 1867mt in 2008, which is consistent with fishermen's accounts of encountering large numbers of pollock in that year. However, recreational catch decreased in 2009 to 896 mt. Recreational catch is small relative to commercial landings and has generally been 10% or less. However, during 2000-2004, recreational catch is estimated to have contributed 15-24% of total catch (commercial catch was near the lowest values in the time series for these same years, Figure C1).

Discard mortality in the recreational catch is assumed to be 100%, consistent with the 100% discard mortality assumed for commercial discards.

Recreational catch was assumed to be negligible prior to 1981 and there is no agreed method upon which to base hindcasted estimates.

Data and assessment

The previous assessment of pollock was conducted with an index-based model (AIM) that used total commercial landings and mean kg/tow from the NEFSC fall survey. A new assessment model (ASAP) was developed which incorporates age structure, additional surveys, more comprehensive catch information, changes in selectivity and uncertainty in the input data.

Catch at age for 1970-2009 are used for two fleets: a composite commercial and a recreational fleet. The commercial fleet includes US catch by otter trawl and gillnet (with minor contributions from hook and line gear), as well as landings by distant water fleets (1970-1976) and Canadian fleets (1970-1985). Total discards for the commercial fleet are estimated for 1989-2008 from observer data. Recreational catch was included for 1981 to 2009.

NEFSC Spring and Fall surveys (1970-2009) number/tow were used in the ASAP model along with estimated CV and annual age composition.

Natural mortality was assumed to be 0.2 for all ages and years, corresponding to 1% survival to age 24 (the maximum age observed). Maturity at age was assumed constant for all years.

Biological Reference Points

$F_{40\%}$ is recommended as the new proxy for the overfishing threshold (F_{MSY}). A deterministic value of $F_{40\%}$ was estimated from a yield per recruit analysis using 2005-2009 average SSB weights, catch weights, maturity and selectivity at age. Expressed as the average F experienced at ages 5-7 for 2005-2009, the estimate is $F_{40\%,\ 5\text{-}7} = 0.25$ (Figure C3), which corresponds to a fully selected F of 0.41 at age 7.

Stochastic projections at $F_{40\%}$ were used to determine new recommended biomass related reference points (SSB_{MSY} and MSY proxies). The proxy for SSB_{MSY}, the B_{TARGET}, is estimated at 91,000 mt, with 5th and 95th percentiles spanning 71,000 to 118,000 mt. One half of SSB_{MSY} is proposed for $B_{THRESHOLD}$ (45,500 mt).

The proxy for MSY is 16,200 mt, with 5th and 95th percentiles spanning 11,800 to 23,200 mt. The median recruitment was 19.2 million age 1 fish, with 5th and 95th percentiles ranging from 8.3 to 42 million fish. Distributions for SSB_{MSY} and MSY are given in Figure C2.

The biological reference points that had been used previously were based upon the AIM model, which is no longer the recommended model for assessing this stock.

Fishing Mortality

Since 1970, there has been a shift in fishery selectivity towards older ages. To provide a consistent metric for expressing F over the time series, an unweighted average F for ages 5-7 ($F_{5\text{-}7}$) was used. In 1970, $F_{5\text{-}7}$ was 0.11, increased to 0.48 by 1986, and then steadily decreased to 2006, when it reached the time series low of 0.03. During 2007 – 2009, $F_{5\text{-}7}$ was 0.05, 0.08, and

0.07, respectively (Figure C3). The uncertainty in the estimate of F_{5-7} in 2009 is described in Figure C4.

To provide a historical perspective on fishing mortality, a time series of $F_{40\%}$ corresponding to ages 5 through 7 is plotted along with the ASAP model estimate of F_{5-7} (Figure C3). This year-specific $F_{40\%}$ accounts for selectivity at age which has changed substantially through time. The fishing mortality reference point has increased significantly since the mid 1990s with the shift of fishing pressure towards older age groups (Figure C5). Overfishing was occurring during the period 1980-1990.

Biomass

The ASAP model estimates a 1970 spawning stock biomass (SSB) of 297,000 mt. Spawning biomass decreased to the time series low (68,600 mt) in 1990 (Figure C6). Spawning biomass then increased steadily through 2006, with a slight decline during 2007 - 2009. Spawning biomass in 2009 is 196,000 mt (the uncertainty in the estimate of SSB in 2009 is provided in Figure C7).

Total population biomass follows the same trend as SSB (Figure C6). Exploitable biomass ranges from 35% to 70% of spawning biomass over the time series. This substantial difference is due to the estimated dome-shaped fishery selectivities (see Special Comments).

In order to provide an historical picture of biomass status, year-specific SSB_{MSY} proxies were calculated using five year averages of selectivity and weights at age. The year-specific $F_{40\%}$ values were used to make stochastic projections for determining the median equilibrium SSB_{MSY}. The full time series of model estimated recruitments was used in all projections. The estimated year specific SSB_{MSY} proxies range from 91,000 mt to 122,000 mt, and the model estimates of SSB were below SSB_{MSY} during the period 1987-1998 (Figure C8).

Recruitment

Mean recruitment (age 1) was around 21 million fish. Strong year classes were produced in 1971, 1979, 1997, 1998, 1999, and 2001 with about average recruitment in recent years (Figure C9).

Ecosystem Considerations

Pollock is an important but not a dominant piscivore in the ecosystem. The amount of food consumed by pollock is 0.001-0.007% of all energy flows in the Gulf of Maine/Georges Bank ecosystem, and pollock account for 0.5-5% of the total consumption by all finfish in this ecosystem. The abundance, amount of food eaten and per capita consumption peaked in the late 1990s to early 2000s. Pollock probably do not consume a significant amount of most prey species (relative to those spp. biomass, production, or fisheries landings), except for pandalid shrimp and in some years herring.

Special Comments:

- The ASAP model with dome-shaped survey and fishery selectivity implies the existence of a large biomass (35 – 70% of total) of pollock (i.e. cryptic biomass) that neither current surveys nor the fishery can confirm. Assuming full survey selectivity for ages 6 and above reduces stock biomass and associated biomass reference points by 20 – 50%. Notwithstanding this, the stock did not appear to be overfished in either case. Under the

full selectivity assumption, long-term catches can be expected to be reduced by approximately 30%.

- The spatial assessment unit is based on jurisdictional boundaries and may not reflect a single self-sustaining resource.
- There is considerable uncertainty in indices of pollock abundance from trawl surveys. The new NOAA survey vessel *Bigelow* appears to have lower catchability of pollock than the *Albatross*, implying that precision of the survey time series is not likely to improve.

References:

Northern Demersal Working Group. 2010. Stock Assessment of Pollock in US Waters for 2010 50th Northeast Stock Assessment Workshop. NEFSC Ref. Doc. (in prep.)

Tables

Table C1a. Percentiles of pollock spawning stock biomass (000s mt) for projections at $F_{status\ quo}$, 0.75*F40%, and F40%.

	F-status-quo = 0.07 (average F on ages 5-7)								
YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
2010	138.5	153.8	160.8	175.9	194.3	213.5	233.0	249.5	270.7
2011	130.7	143.5	149.5	163.2	179.8	196.6	215.6	229.8	250.1
2012	127.1	137.6	143.6	156.4	171.6	187.0	204.5	218.0	237.6
2013	123.6	133.9	140.5	152.5	166.6	181.4	198.0	209.4	228.6
2014	124.1	134.0	140.2	151.9	165.0	179.2	194.9	205.0	223.8
2015	125.5	135.2	141.4	152.4	164.9	178.8	193.7	202.8	221.3
2016	126.5	136.7	142.6	153.2	165.8	179.8	194.1	203.1	221.0
2017	126.5	136.8	142.7	153.3	166.2	180.5	194.9	204.1	221.8

	0.75*F40% = 0.19 (average F on ages 5-7)								
YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
2010	138.5	153.8	160.8	175.9	194.3	213.5	233.0	249.5	270.7
2011	122.5	134.2	139.9	152.8	168.3	184.3	202.2	214.8	234.0
2012	112.3	121.1	126.6	138.0	151.2	165.1	180.7	191.7	209.8
2013	104.1	112.8	118.1	128.5	140.0	152.6	166.5	176.2	192.7
2014	100.1	108.0	113.0	122.4	132.8	144.3	156.8	165.0	180.8
2015	96.9	104.7	109.3	117.8	127.6	138.5	149.8	157.1	171.4
2016	93.7	101.4	105.8	113.9	123.5	134.4	145.5	152.6	166.1
2017	90.2	97.8	102.2	110.1	120.0	131.2	142.5	149.7	163.6

	F40% = 0.25 (average F on ages 5-7)								
YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
2010	138.5	153.8	160.8	175.9	194.3	213.5	233.0	249.5	270.7
2011	118.5	129.6	135.2	147.7	162.6	178.0	195.5	207.6	226.2
2012	105.3	113.4	118.9	129.7	142.0	155.0	169.6	180.0	197.1
2013	95.7	103.4	108.4	117.9	128.5	140.0	152.8	161.4	177.0
2014	90.0	97.1	101.7	110.0	119.4	129.8	141.0	148.4	162.8
2015	85.4	92.4	96.5	103.9	112.6	122.4	132.4	138.9	151.5
2016	81.0	87.7	91.6	98.6	107.3	117.0	127.0	133.5	145.7
2017	76.6	83.2	86.9	93.9	102.8	112.8	123.2	129.7	142.4

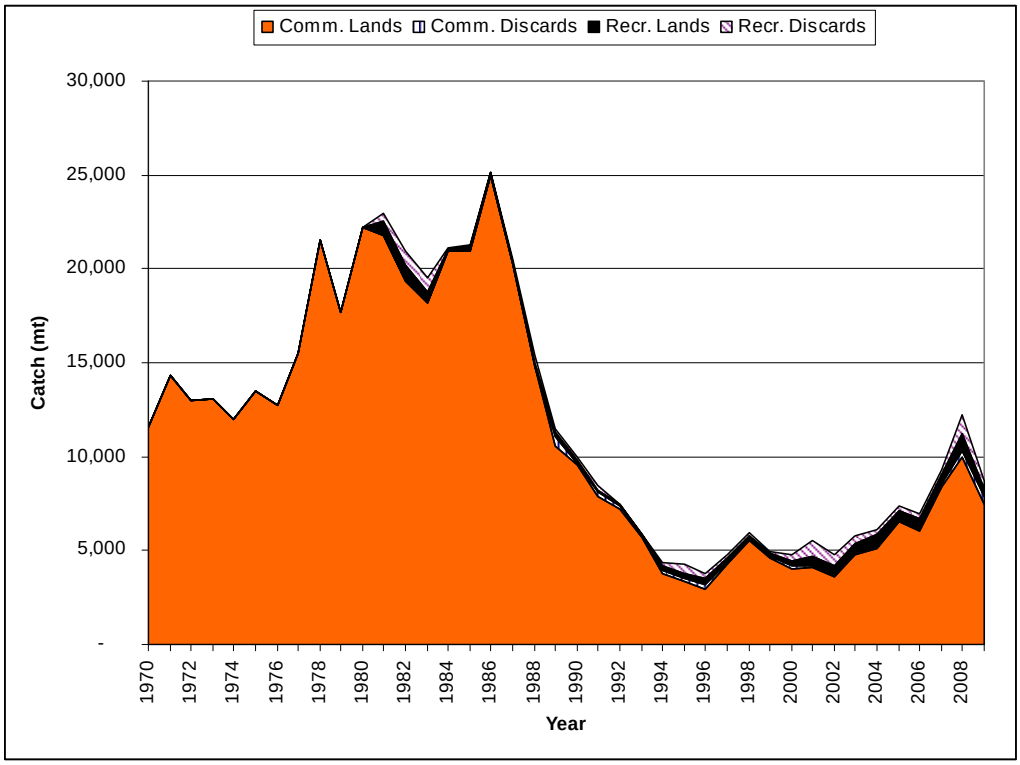
Table C1b. Percentiles of catch (000s mt) of pollock for projections at $F_{status\ quo}$, 0.75*F40%, and F40%.

	F-status-quo = 0.07 (average F on ages 5-7)								
YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
2010	5.8	6.4	6.7	7.3	8.1	8.7	9.6	10.2	11.2
2011	5.5	6.0	6.2	6.8	7.5	8.1	8.8	9.4	10.4
2012	5.3	5.7	6.0	6.6	7.2	7.8	8.5	9.0	9.8
2013	5.5	6.1	6.3	6.9	7.5	8.2	9.0	9.4	10.3
2014	5.9	6.5	6.8	7.3	8.0	8.8	9.6	10.1	11.1
2015	6.3	6.8	7.1	7.7	8.4	9.2	10.0	10.5	11.6
2016	6.4	7.0	7.3	7.8	8.5	9.3	10.2	10.7	11.7
2017	6.1	6.6	7.0	7.6	8.4	9.3	10.5	11.3	12.6

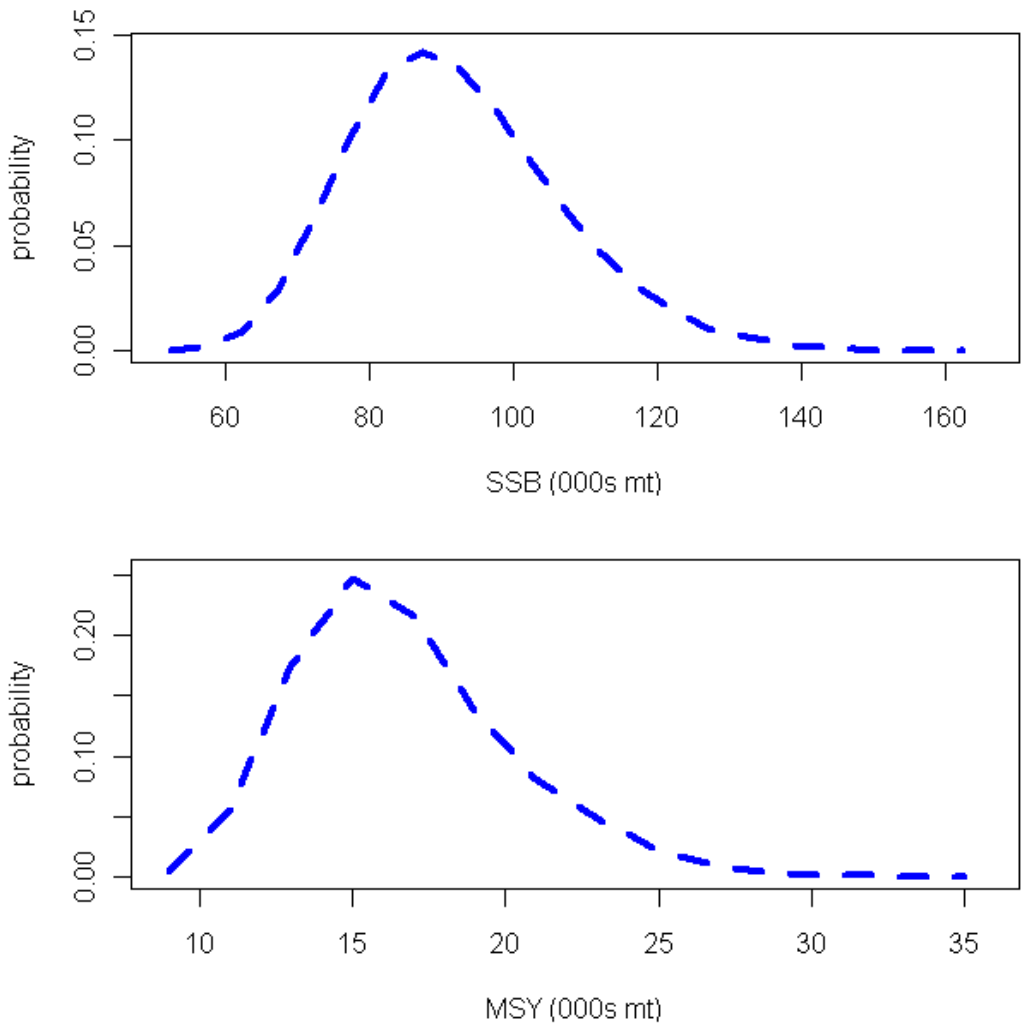
	0.75*F40% = 0.19 (average F on ages 5-7)								
YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
2010	14.3	15.8	16.5	17.9	19.8	21.5	23.6	25.0	27.6
2011	12.4	13.5	14.1	15.3	16.9	18.4	20.0	21.2	23.4
2012	11.4	12.3	12.9	14.1	15.4	16.8	18.3	19.4	21.0
2013	11.4	12.5	13.1	14.2	15.6	17.0	18.5	19.5	21.3
2014	11.8	12.9	13.5	14.6	16.0	17.6	19.2	20.2	22.3
2015	12.2	13.3	13.9	15.0	16.3	17.9	19.4	20.4	22.5
2016	12.1	13.1	13.7	14.8	16.1	17.7	19.4	20.6	22.7
2017	11.0	12.1	12.7	14.0	15.6	17.5	19.8	21.4	24.0

	F40% = 0.25 (average F on ages 5-7)								
YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
2010	18.6	20.4	21.3	23.2	25.7	27.9	30.5	32.4	35.8
2011	15.3	16.7	17.5	19.0	21.0	22.8	24.8	26.3	29.0
2012	13.8	14.9	15.6	17.1	18.6	20.3	22.2	23.4	25.4
2013	13.5	14.9	15.5	16.9	18.4	20.1	22.0	23.1	25.3
2014	13.7	15.0	15.7	17.0	18.6	20.5	22.4	23.5	26.0
2015	14.1	15.3	16.0	17.2	18.7	20.6	22.3	23.5	25.9
2016	13.7	14.9	15.6	16.8	18.3	20.2	22.2	23.6	26.2
2017	12.3	13.5	14.2	15.7	17.5	19.8	22.6	24.4	27.4

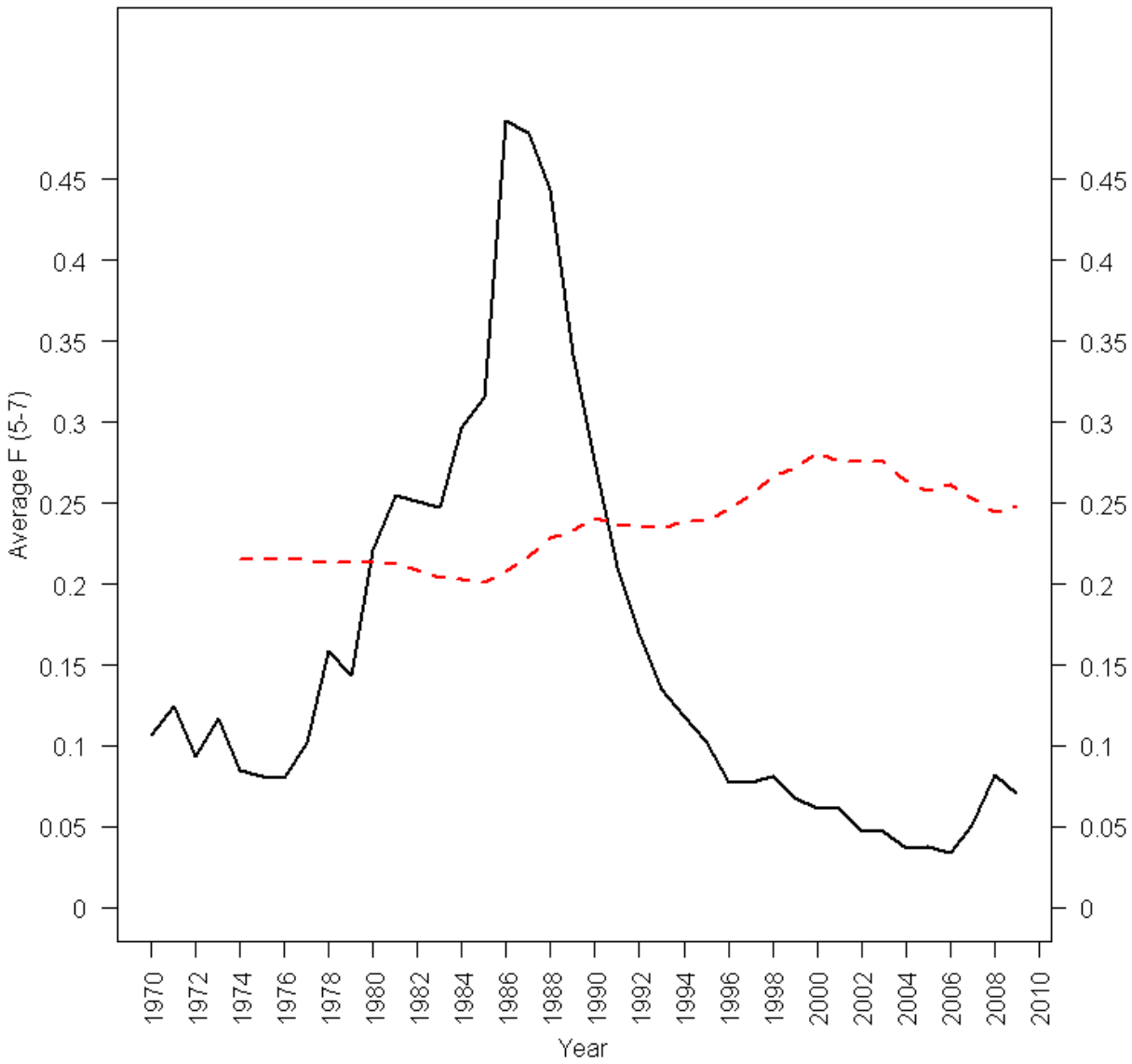
Figures



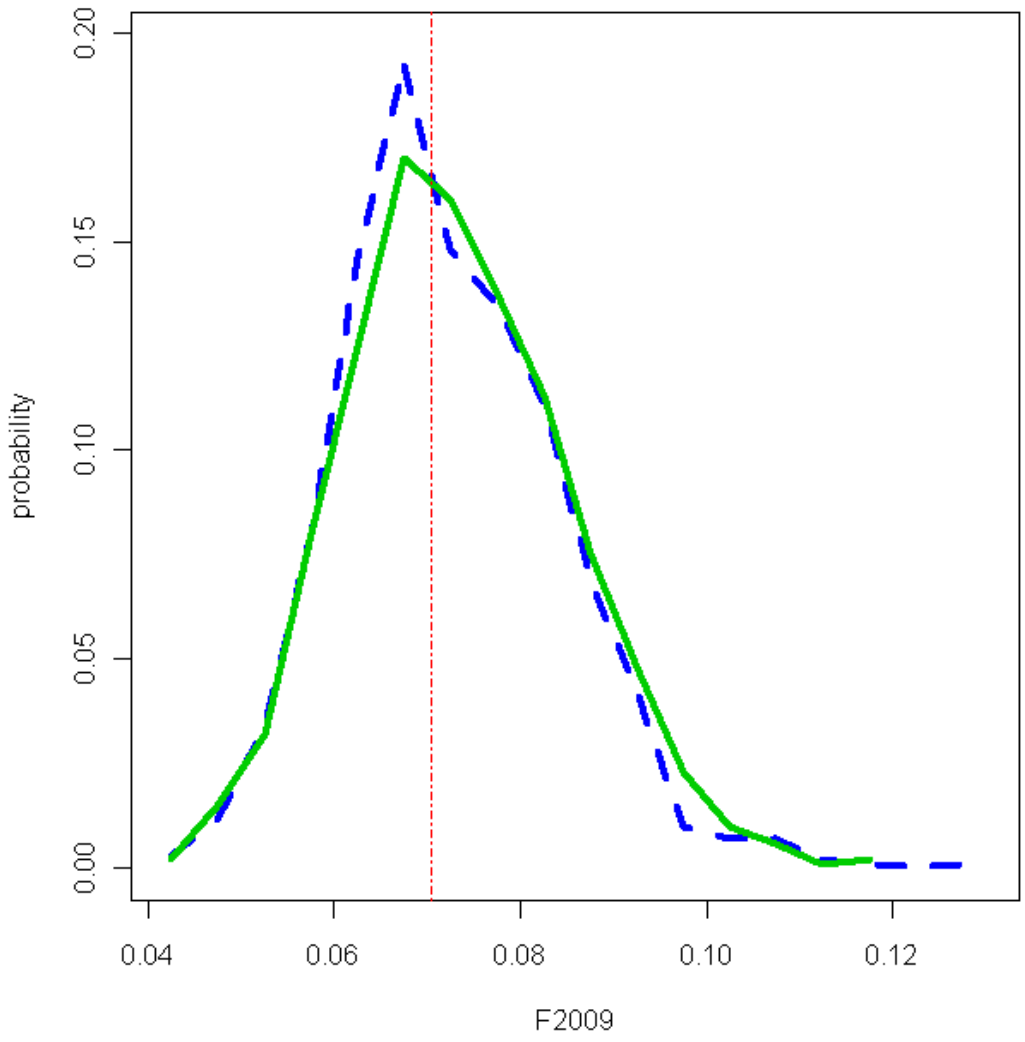
C1. Components of total pollock catch by fleet (Commercial and Recreational).



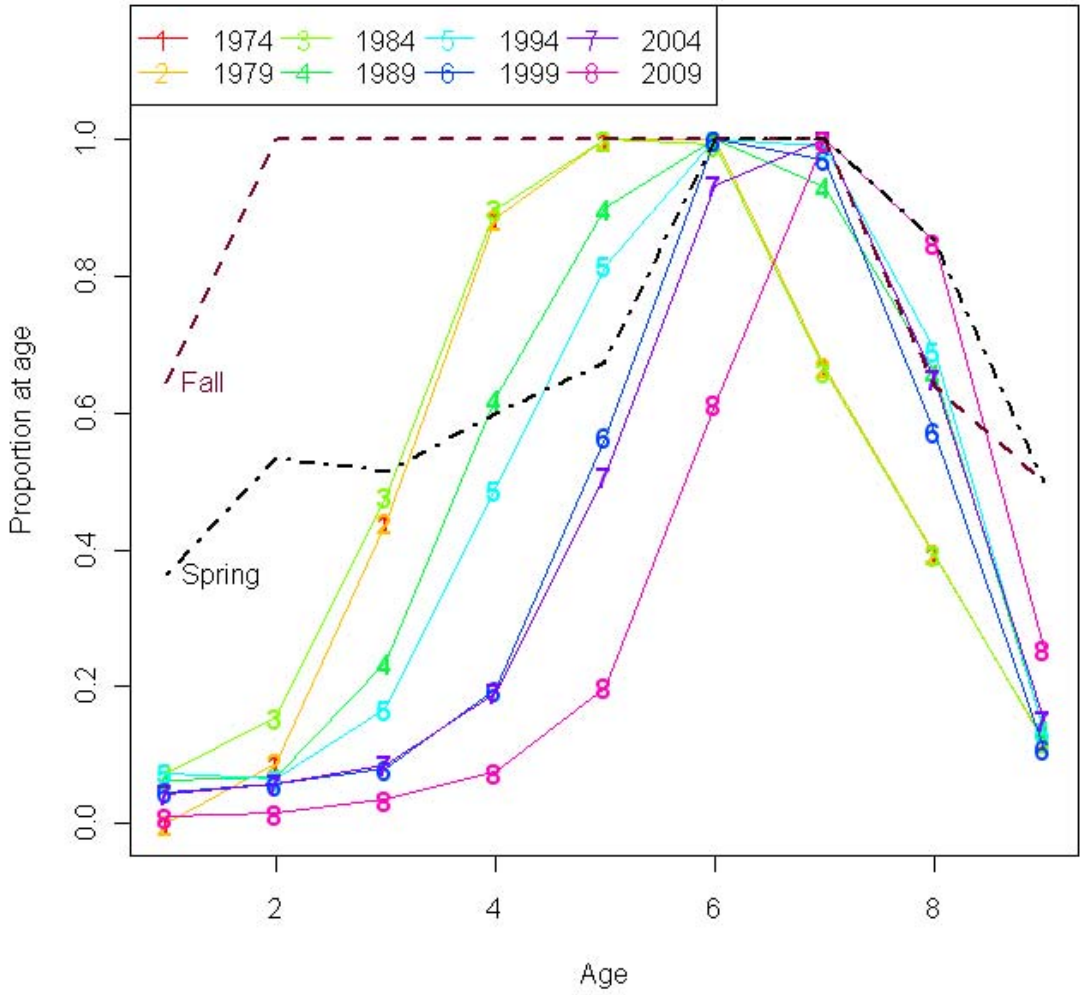
C2. Distributions of SSB_{MSY} and MSY for pollock based on stochastic projections at $F_{40\%}$. The median estimates are 91,000 mt for SSB_{MSY} and 16,200 mt for MSY, based on projections that used $F_{40\%}$ as a proxy for F_{MSY}. The MSY amount includes both commercial and recreational landings and discards.



C3. ASAP model estimated time series of average F on ages 5-7 for pollock. The dashed red line is $F_{40\%}$ on ages 5-7, calculated for years 1974-2009 with a 5 year moving average of weights at age, selectivity at age, and maturity at age. The $F_{40\%}$ in 1974 used years (1970-1974) while the final $F_{40\%}$ used years (2005-2009).

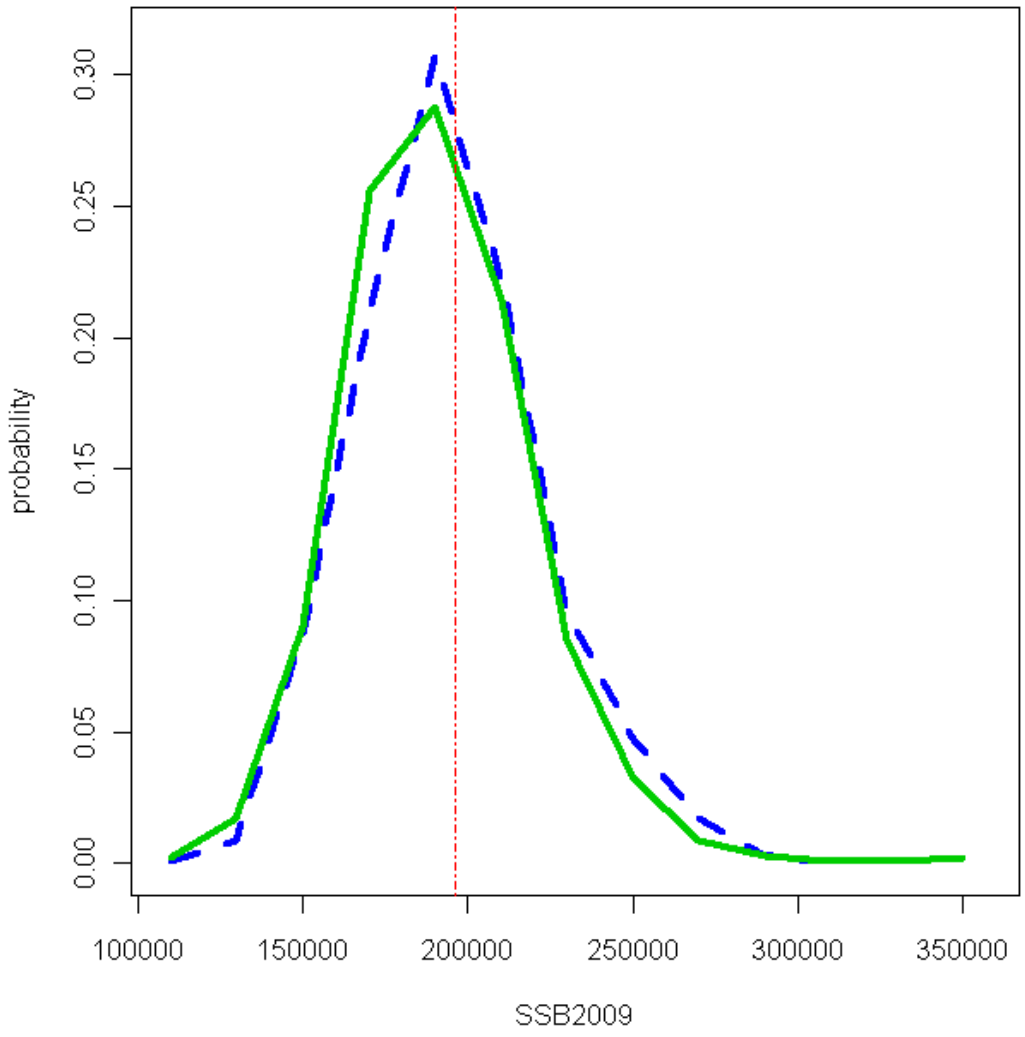


C4. Uncertainty in average F on ages 5-7 ($F_{5\text{-}7}$) pollock in 2009 for two MCMC chains (dotted blue and solid green lines). The vertical dashed red line indicates the point estimate.

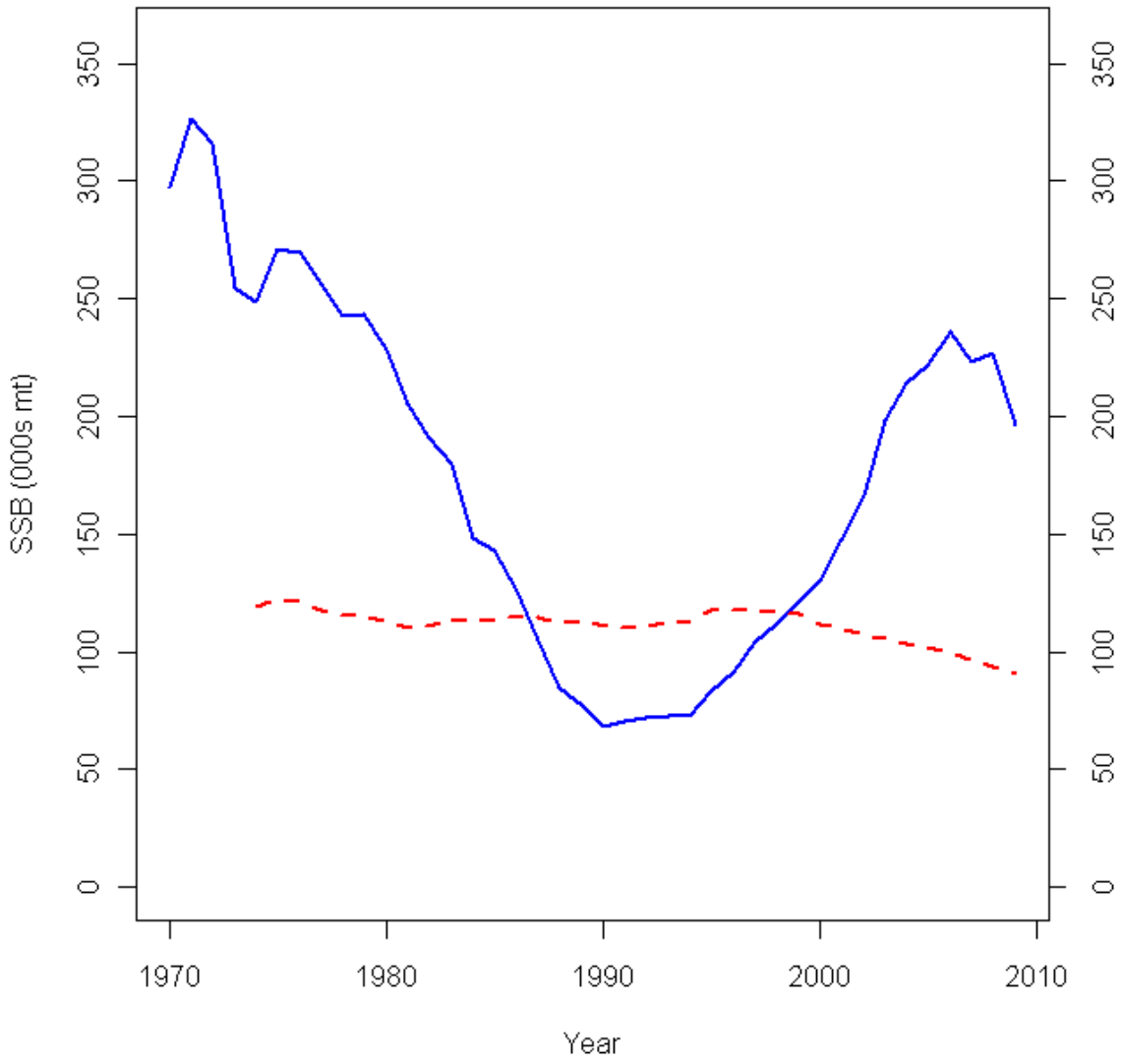


C5. ASAP model estimates for NEFSC Fall and Spring index selectivities for pollock (dashed, and dot-dash, respectively) compared to 5-year average fleet selectivities. Average selectivity at age for the 1st 5-year period includes estimates from 1970-1974 (line with '1' for point symbols) while the last 5-year average includes estimates from 2005-2009 (line with '8' for point symbols).

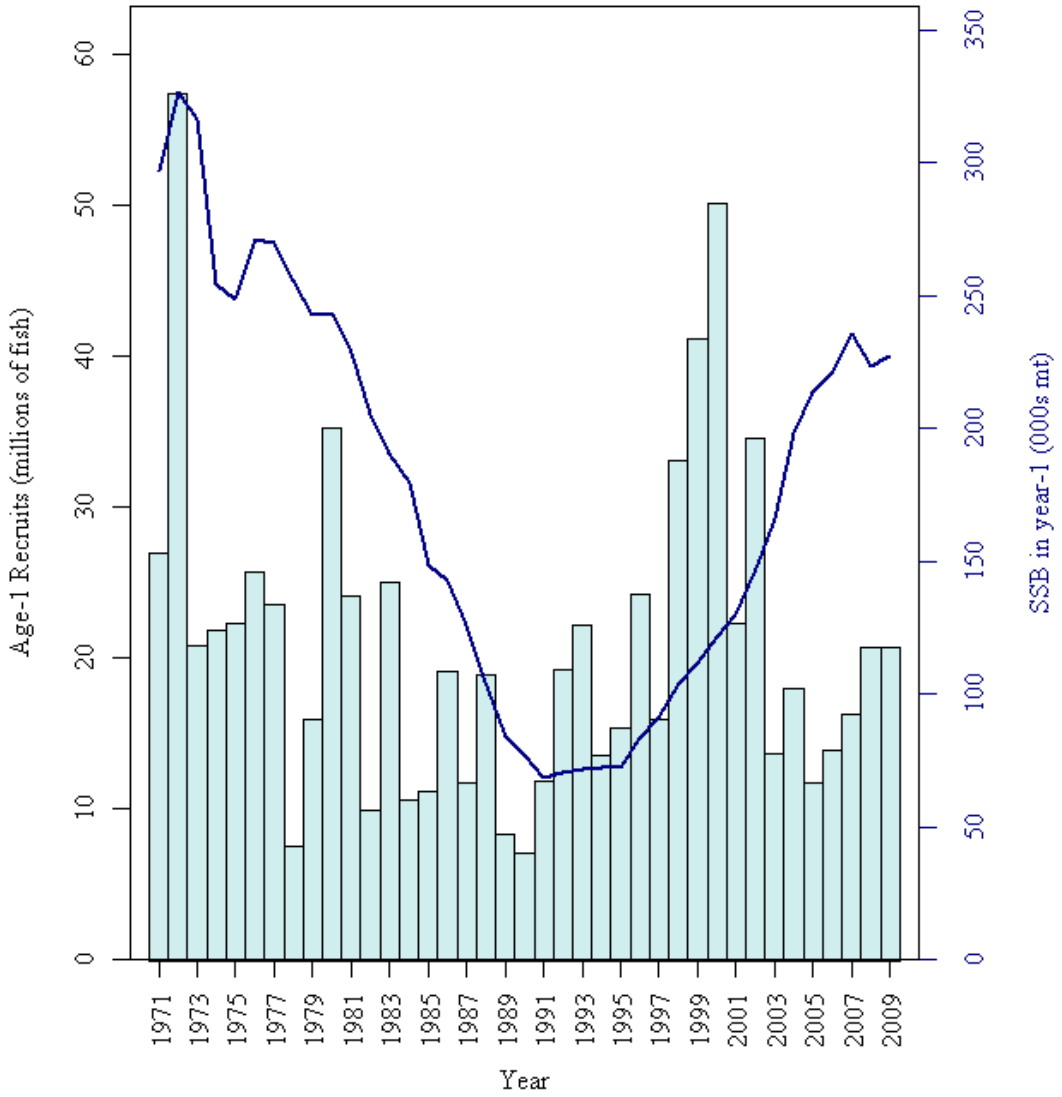
C6. Annual estimates of three biomass measures (total biomass, spawning stock biomass, and exploitable biomass in mt) for pollock based on the ASAP model.



C7. Posterior distribution for pollock spawning stock biomass (SSB) in 2009 for two MCMC chains (dotted blue and solid green lines). The vertical dashed red line indicates the point estimate.



C8. ASAP model estimated time series of pollock spawning stock biomass (solid line). The dashed red line is the corresponding SSB_{MSY} proxy calculated from stochastic projections at year-specific F40% with a 5 year moving average of weights at age, selectivity at age, and maturity at age. SSB_{MSY} in 1974 used years (1970-1974) while the final SSB_{MSY} used years (2005-2009).



C9. Time series plot of pollock spawning stock biomass in year t-1 (solid line) and recruitment of age-1 fish in year t (solid bars).