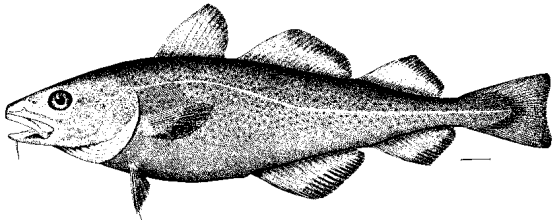
Georges Bank Cod



Gadus morhua

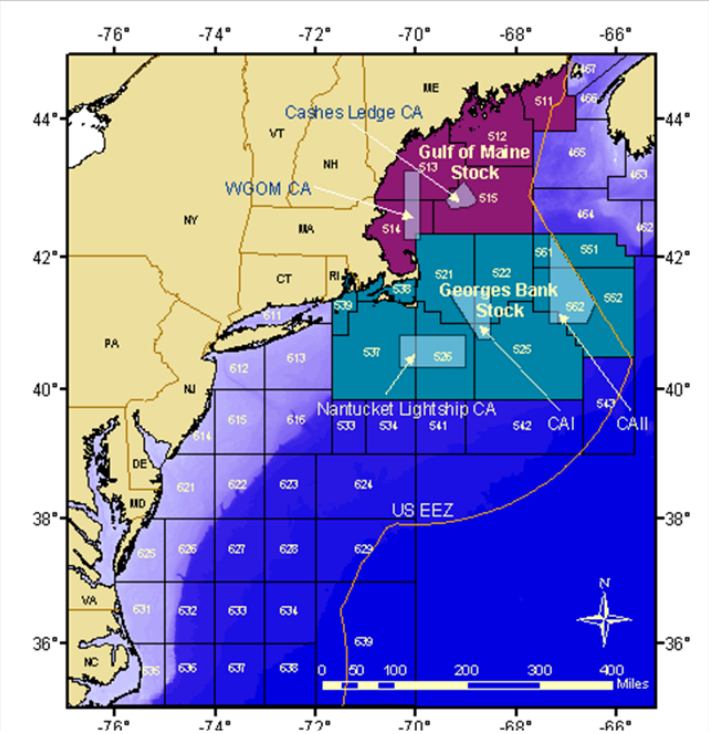
Groundfish Operational Assessment Review Meeting
NEFSC
Woods Hole, Ma
September 14-18, 2015

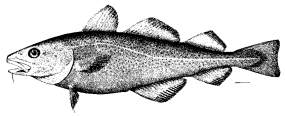
Last assessed:
2012 SARC 55 Benchmark

Statistical CAA model :
ASAP; Terminal year = 2010

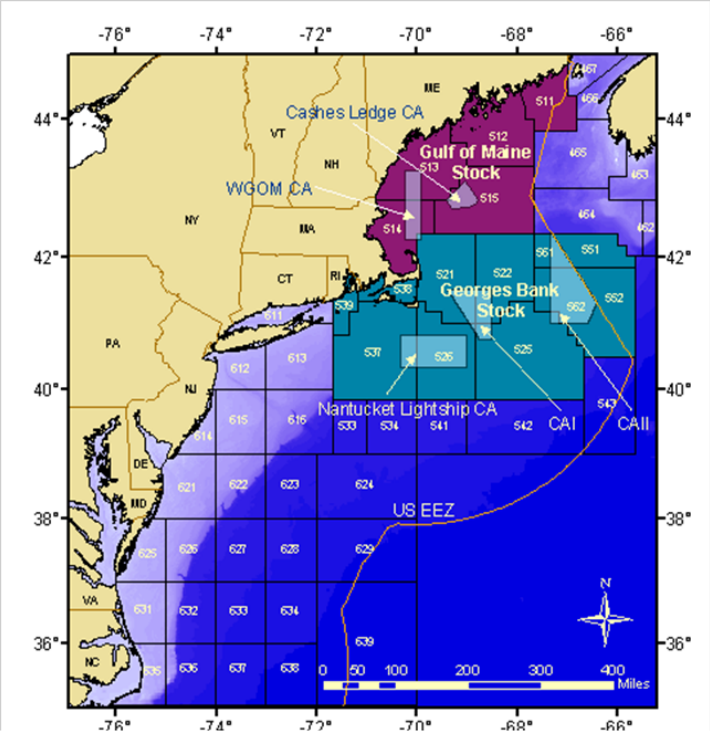
Reference Points:
$F_{40\%} = 0.177$
MSY = 30,622 mt
SSB_{MSY} = 186,535 mt

Status in 2012:
Overfished : 2011 SSB = 13,217 mt (retro adjusted)
Overfishing occurring: 2011 F = 0.42 (retro adjusted)





2015 Operational assessment:



Statistical CAA model :

Accepted Benchmark ASAP; TY = 2014

Reference Points:

$F_{40\%}$ = 0.169

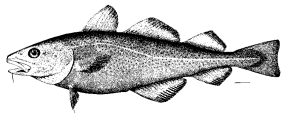
MSY = 30,570 mt

SSB_{MSY} = 201,466 mt

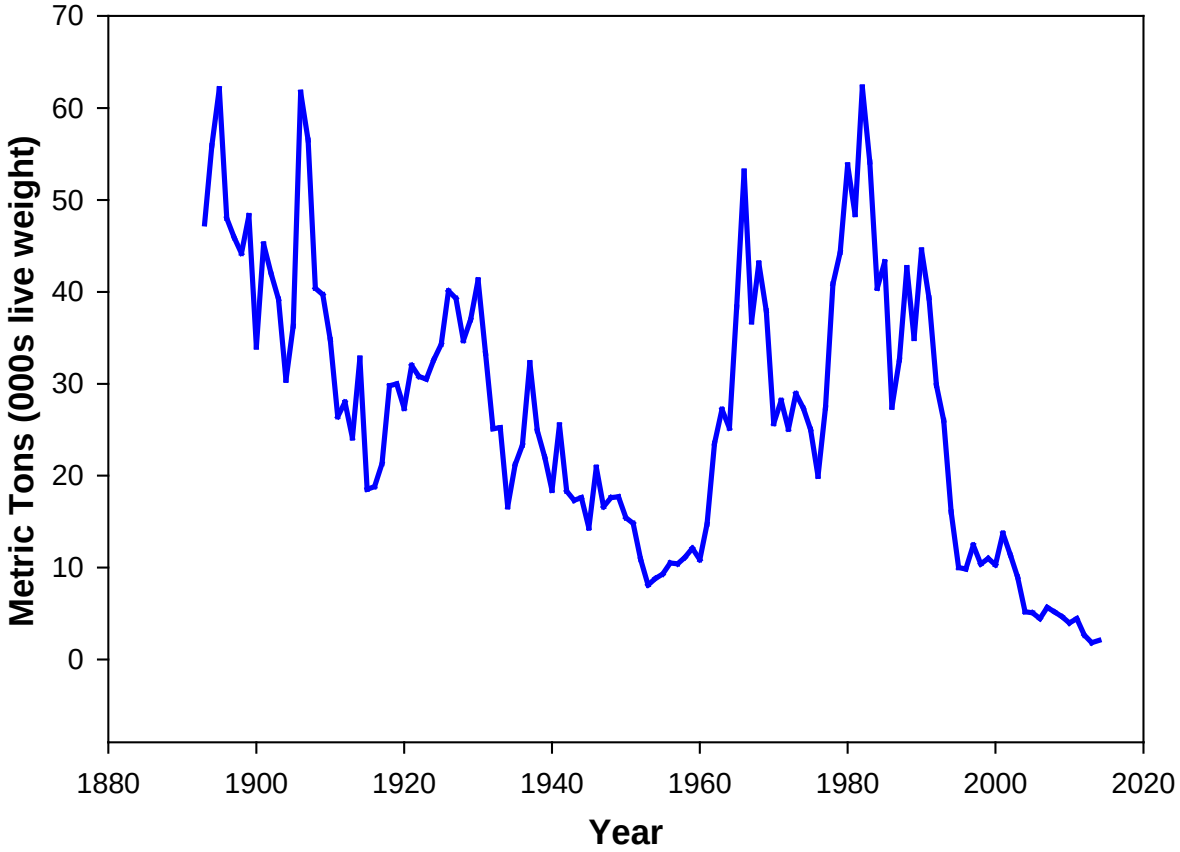
Status in 2015:

Overfished : 2014 SSB = 1,966 mt (retro adjusted)

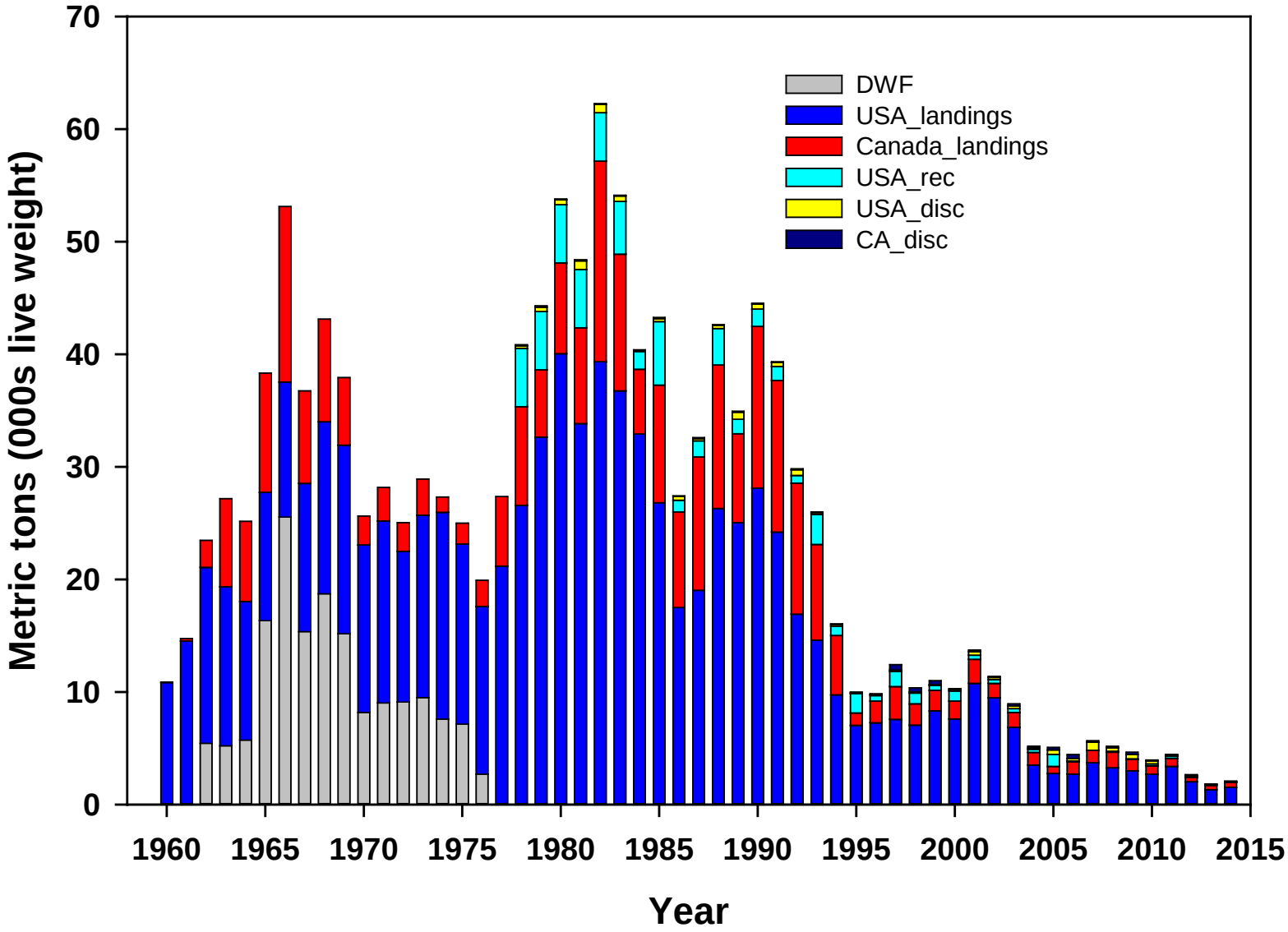
Overfishing occurring: 2014 F = 1.61 (retro adjusted)



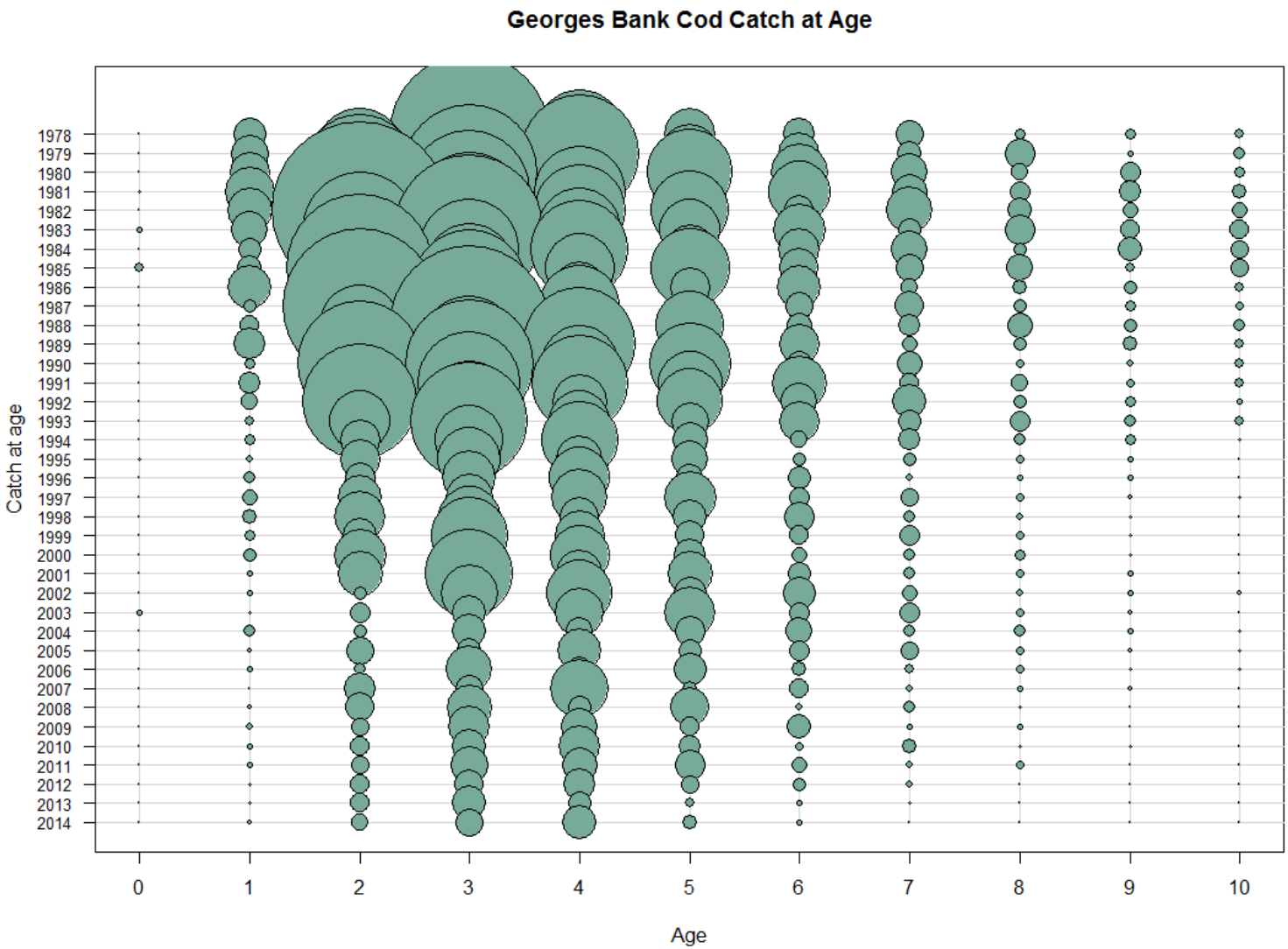
Total Catch of GB cod since 1893



Catch - 1960 -2014 ; DWF, US, CA



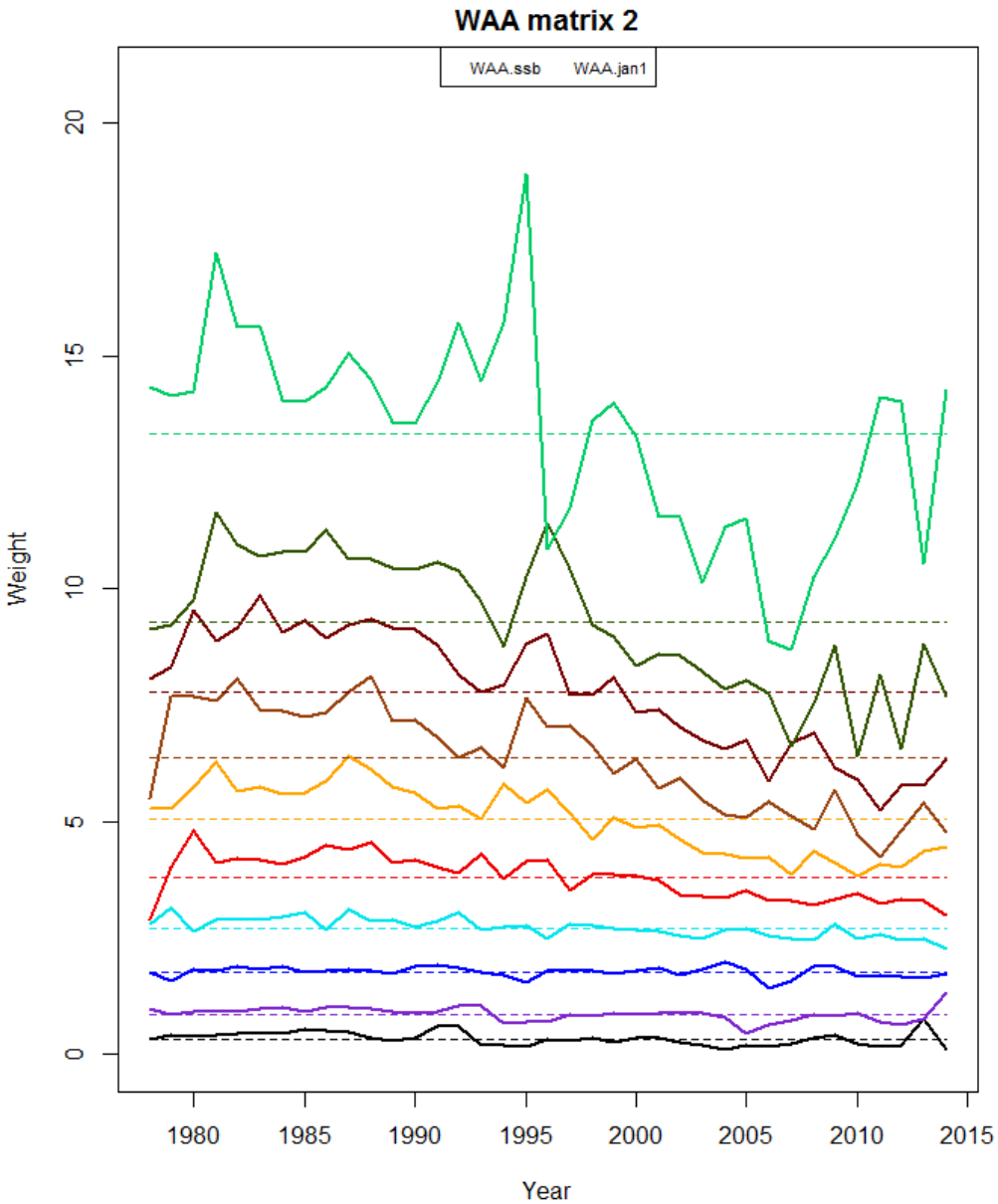
Total Catch: US comm. & rec., CA comm.



2014, 1st yr
No age 9, 10+
In CA fishery

See Table 8b.

Total Catch – Jan. 1 avg wt at age (1 – 10+)



Age 10

Age 1

Survey wt/tow - standardized to mean

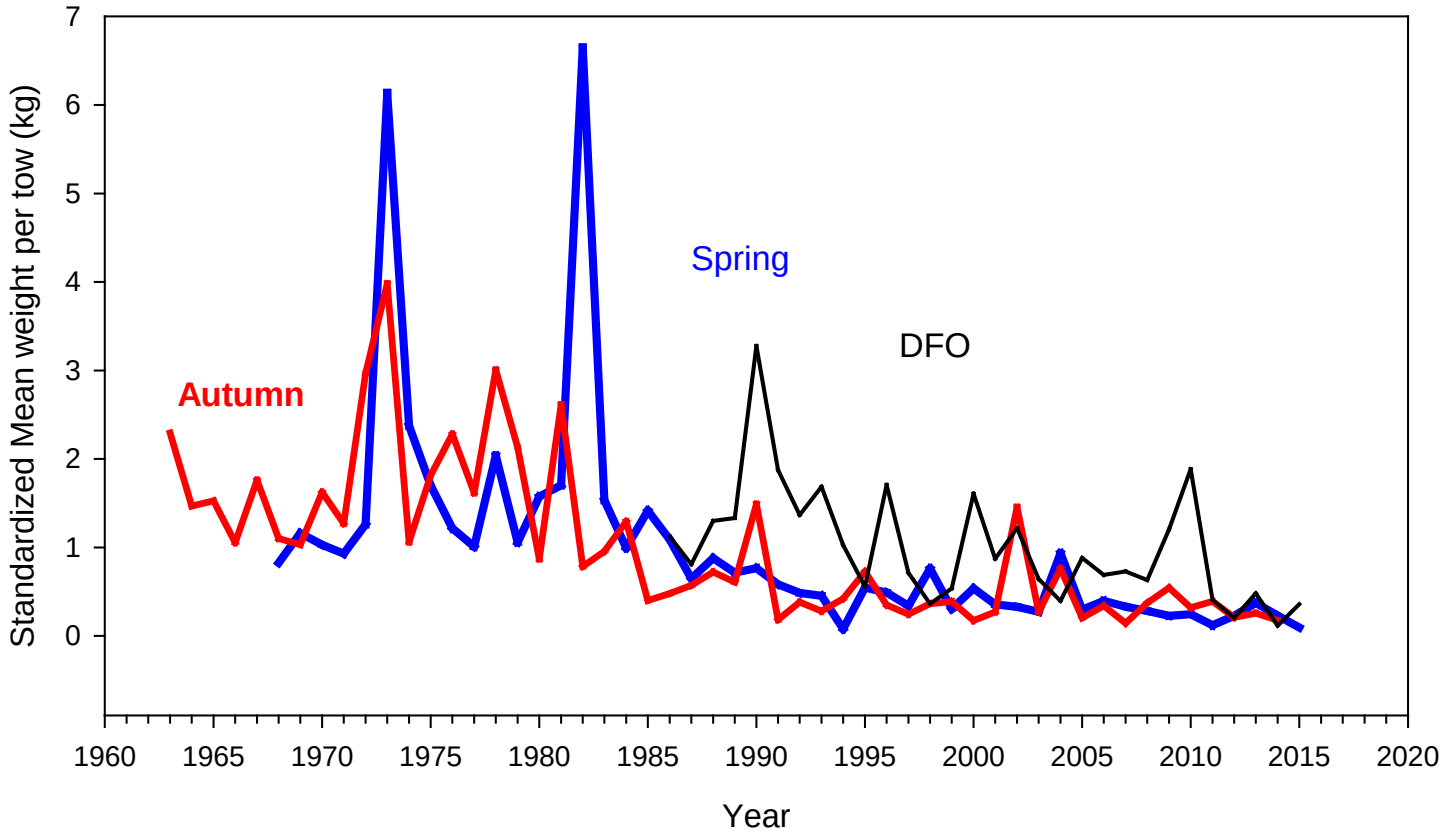
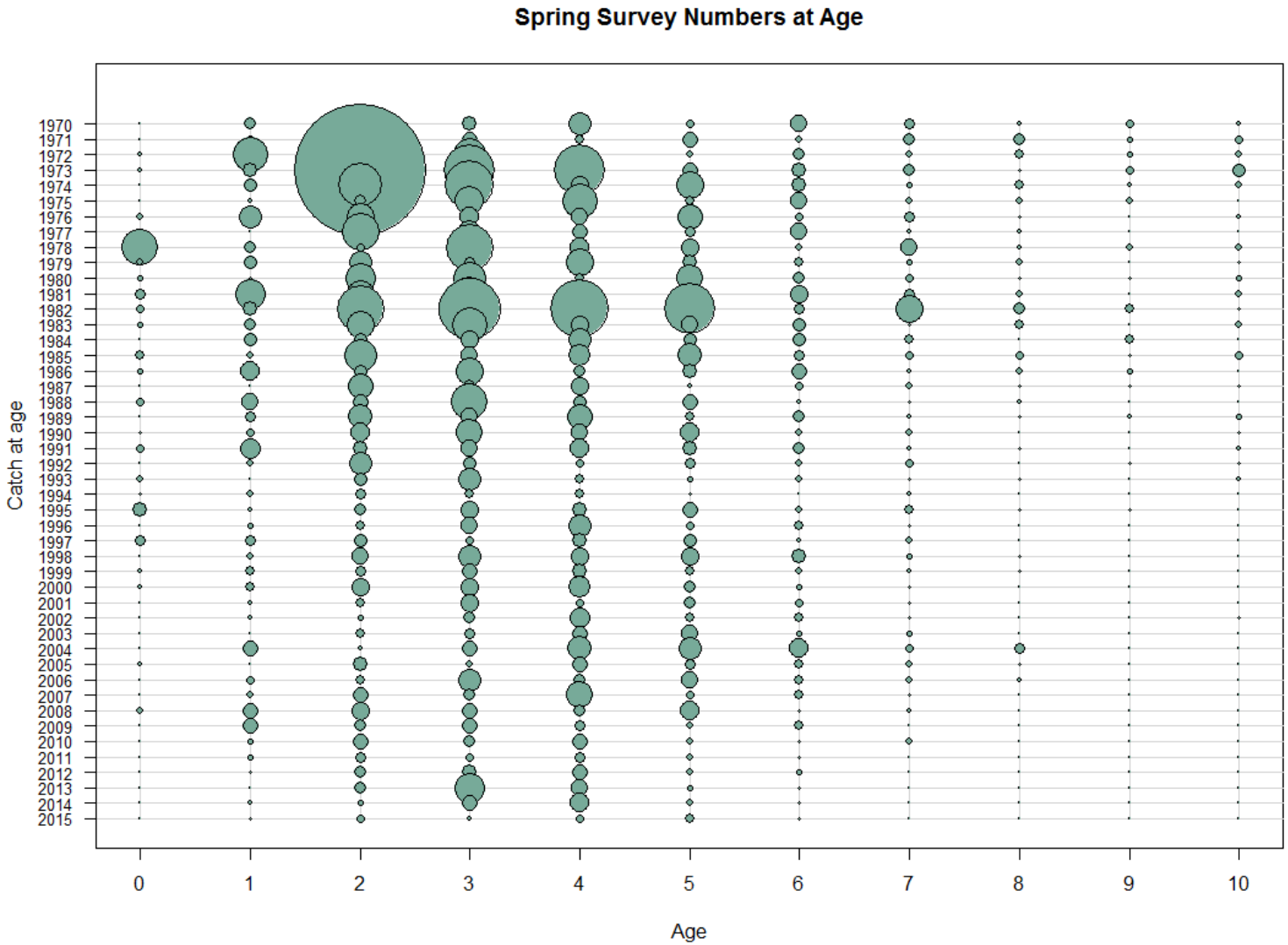
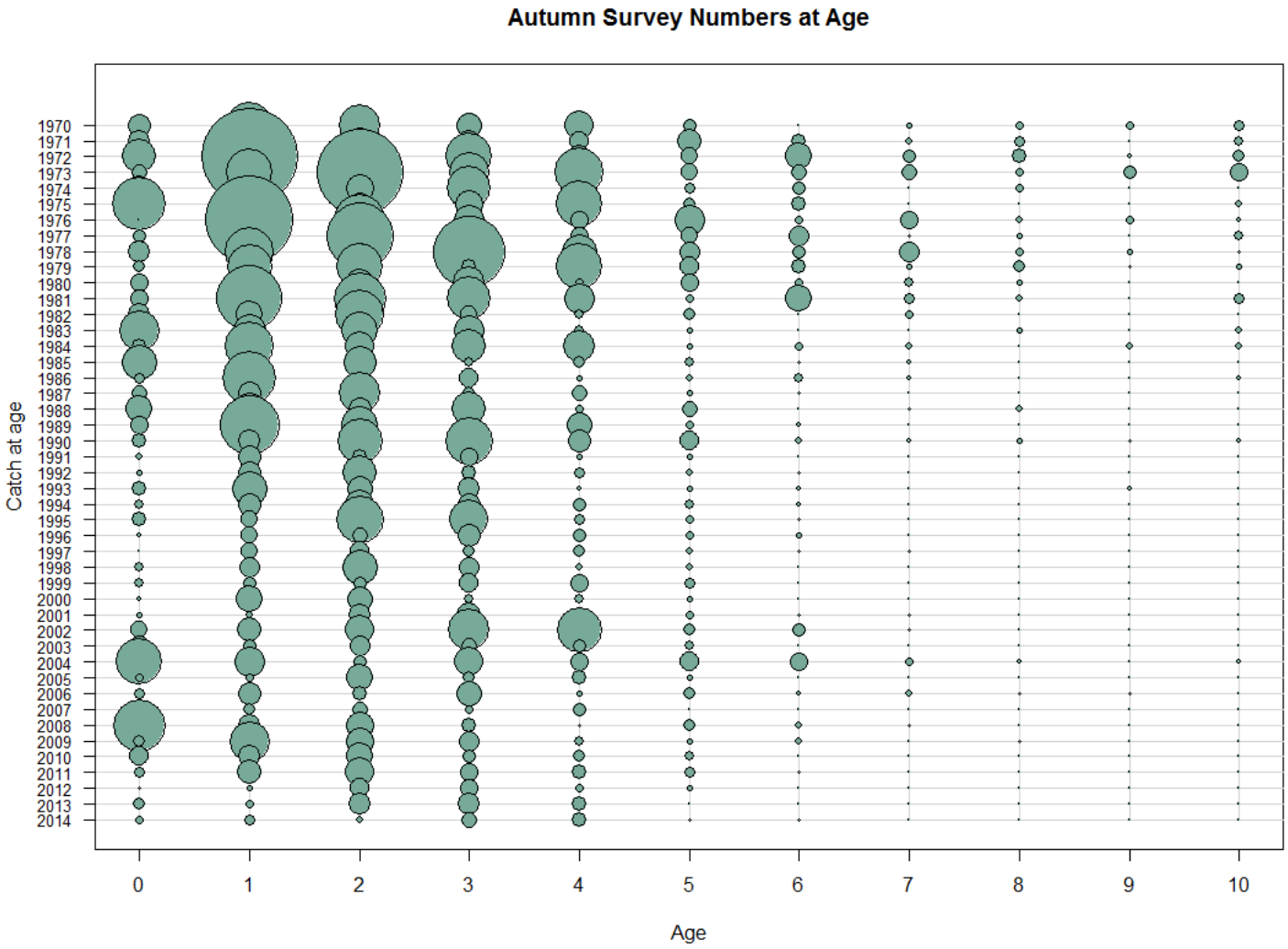


Table 11, Figure 5 - Report

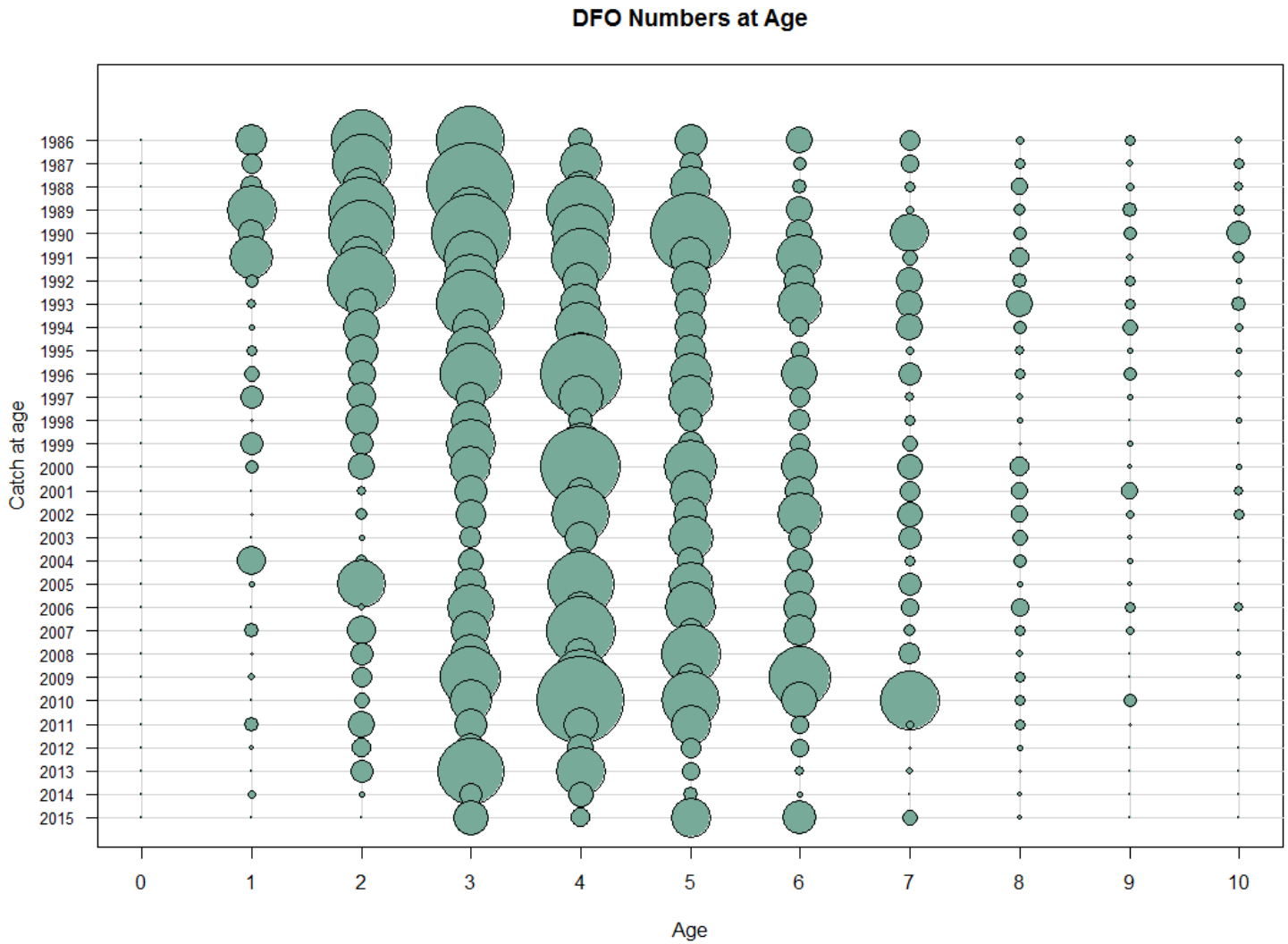
NEFSC Spring survey



NEFSC Autumn survey

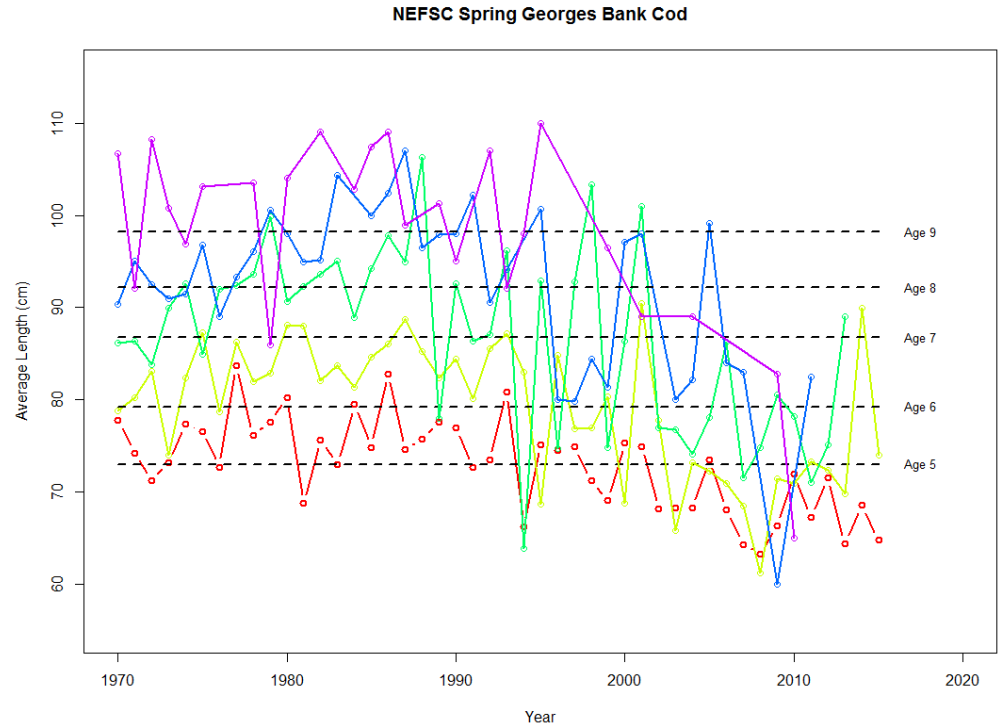


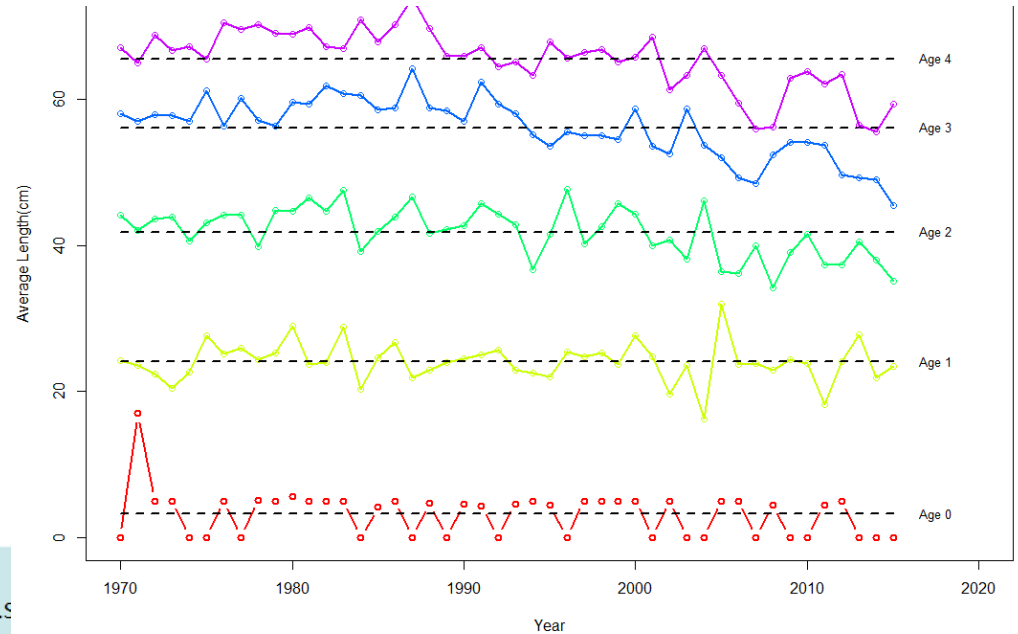
DFO Feb/Mar survey



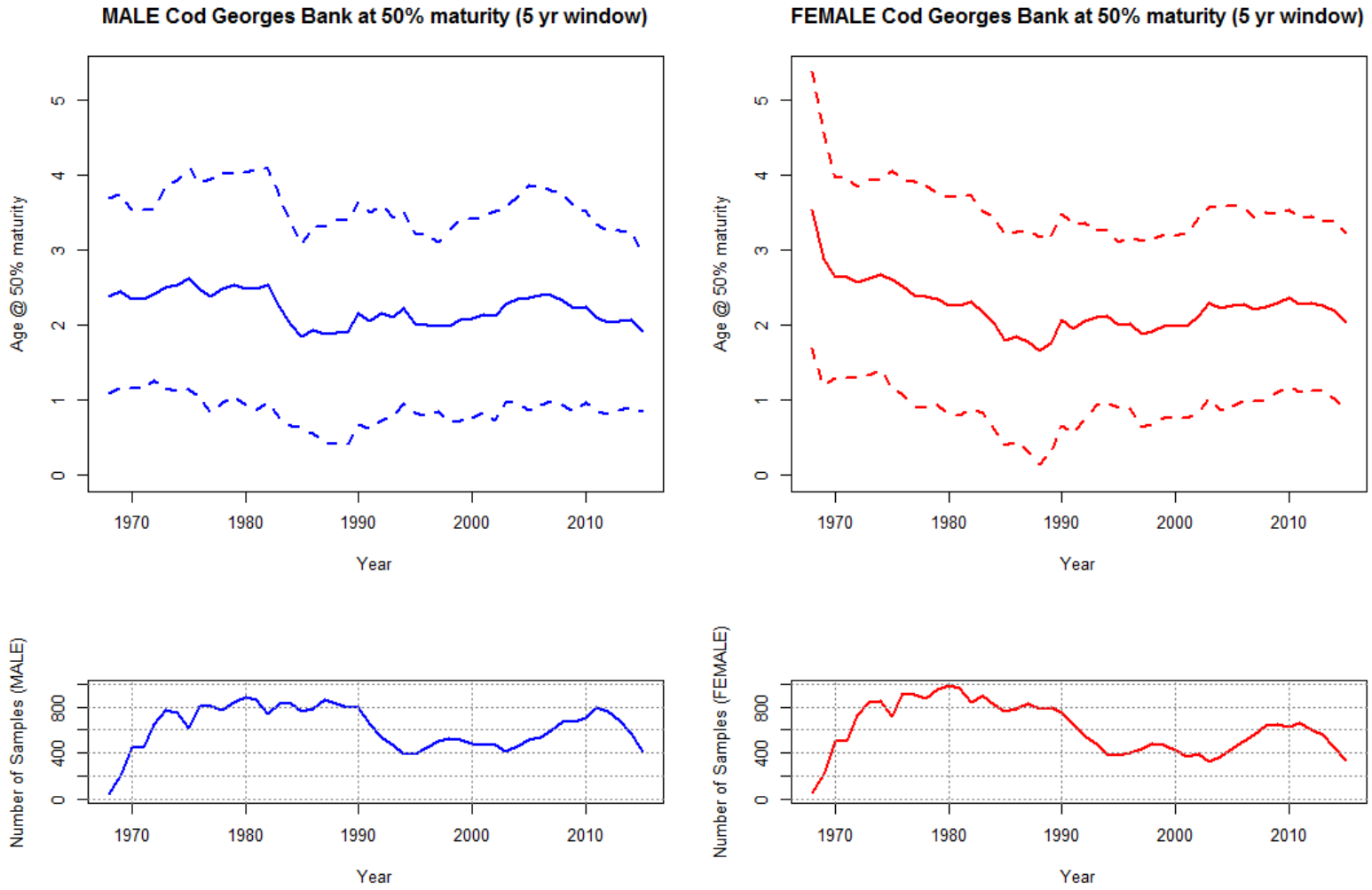
Spring survey

Mean Length at age





Median maturity at age (A50) : 5-yr moving avg (of data)



ASAP Benchmark Model

Ages 1 – 10 +
1978-2014 CAA
Delphi Mortality rate applied to USA discards only

1 Fleet ; 2 Selectivity Blocks
- 1978-1993 ; logistic selectivity (flat)
- 1994-2014 ; logistic selectivity

3 surveys
- Spring NMFS: 1978-2014 ; Ages 1-10, logistic selectivity
- Autumn NMFS: 1978-2014; Ages 1-6 , selectivity at age, fixed age 3 =1
- DFO: 1986-2014; Ages 1-10, logistic selectivity

Split NEFSC Spring Sv: Yankee #41 vs. Yankee #36: 1978-1981 ; 1982-2014

M = 0.2 all ages all years

Fitting

Multinomial distribution : fishery catch at age composition
survey times series and survey age composition

Catch CV = 0.05

Lambda Rec. Dev = 0
Recruitment CV = 0.5

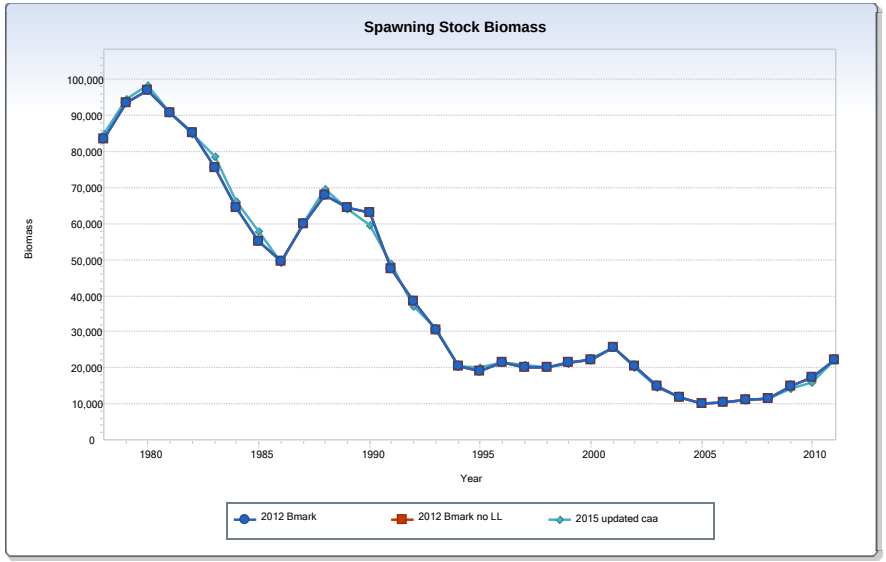
Stock/ Recruit not estimated

Survey CVs
- spring + 0.4, fall + 0.25, DFO + 0.2 added to observed CV estimates

Selectivity:
Fleet : flat-topped
Surveys: flat-topped

Changes in databases and estimation since 2012 Benchmark

have minor effect



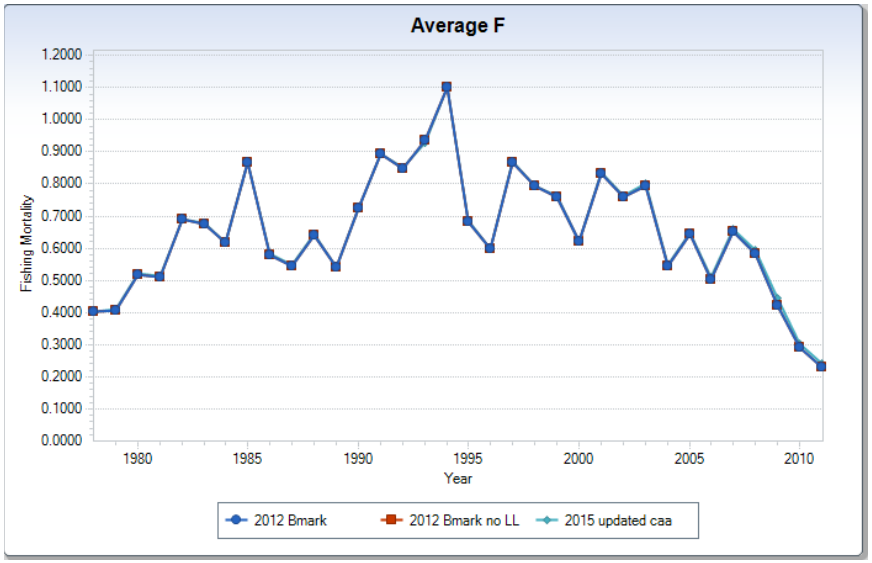
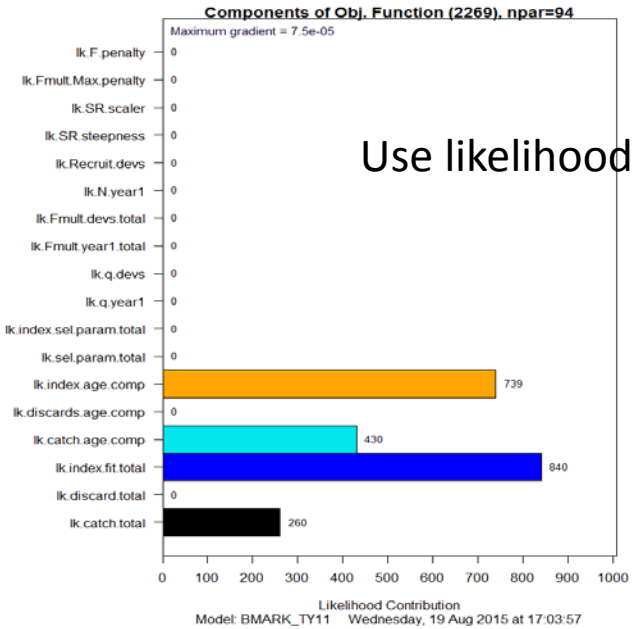


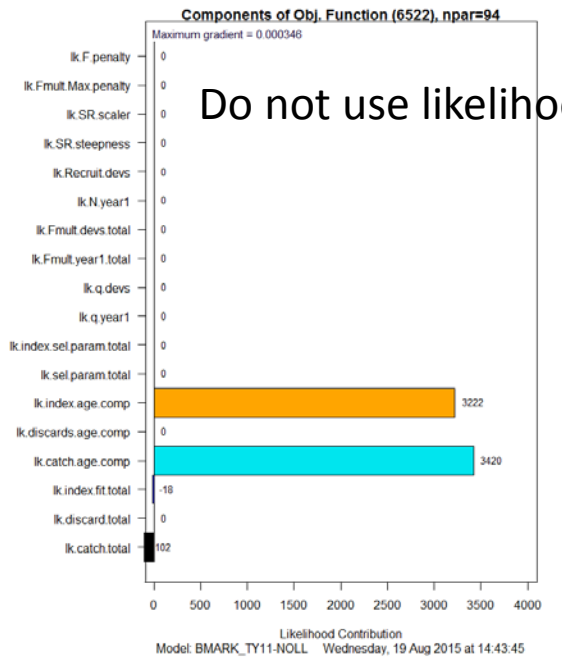
Table 15

Model Diagnostics and Results

For final run with DFO 2012 corrected



Use likelihood constants



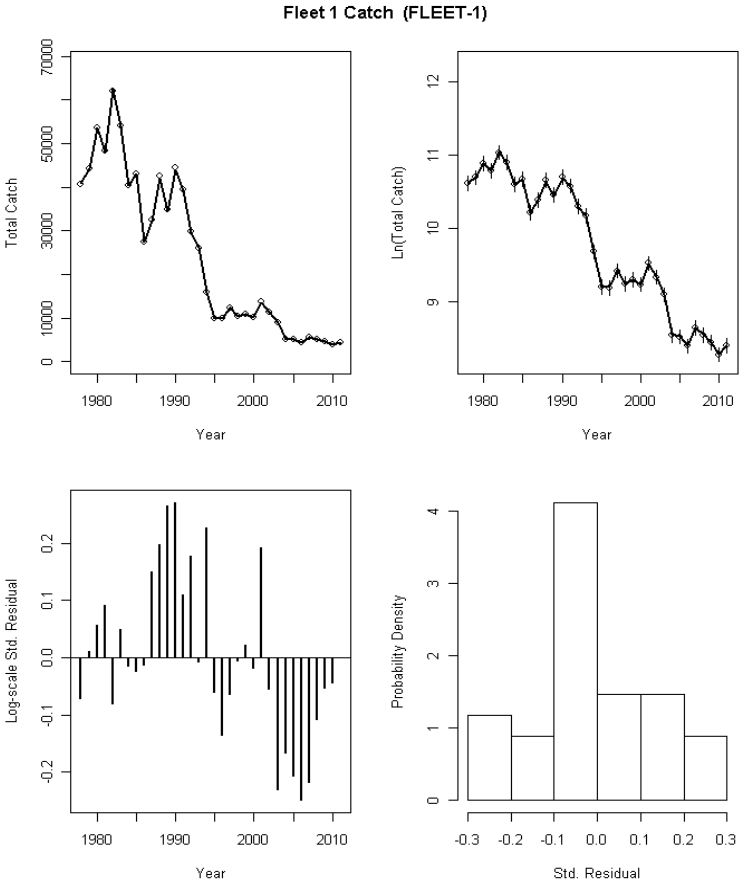
Do not use likelihood constants

Table 15

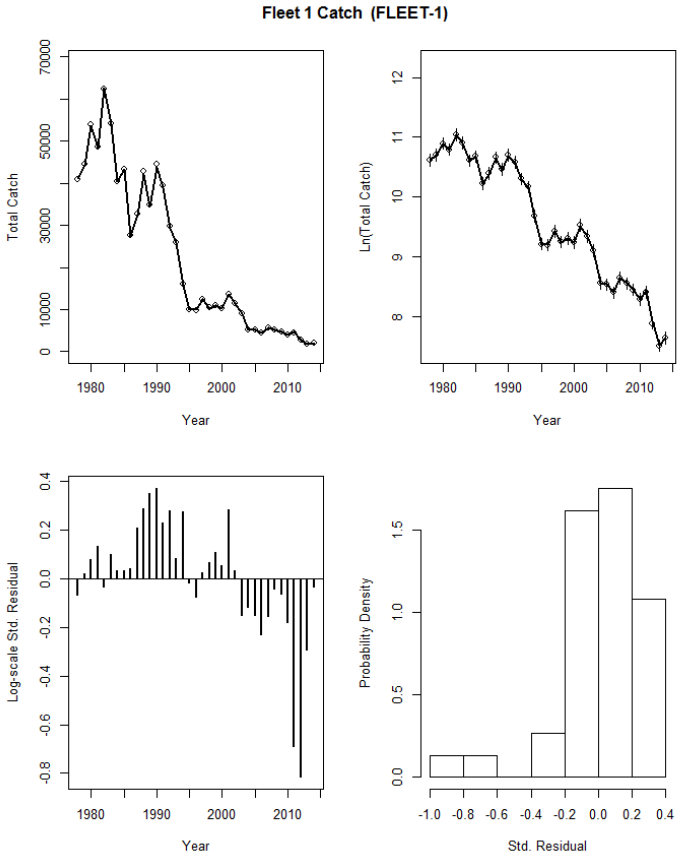
		TY=2011	TY=2011
Model		base_repeat	repeatNO LL
objective function		2269.33	6522.45
components of obj. function			
	catch total	260.398	-101.553
	index fit total	839.96	-17.64
	catch age composition	429.71	3419.89
	Index age composition	739.26	3221.74
	Recruit deviations	0	0
RMSE	Catch fleet	0.14	0.14
	total catch	0.14	0.14
	discards	0.00	0.00
	total discards	0.00	0.00
	DFO	0.92	0.92
	Autumn	1.01	1.01
	Spring 41	1.11	1.11
	Spring 36	0.92	0.92
	Index total	0.96	0.96
CV	catch	0.05	0.05
	dfo	0.2+	0.2+
	fall	0.25+	0.25+
	spring #41	0.1+	0.1+
	spring #36	0.4+	0.4+
ESS	catch	65	65
	dfo	9	9
	fall	14	14
	41	40	40
	36	37	37
Jan 1 biomass		29077	29077
SSB TY mt		22217	22217
SSB TY retro bias adj		13216	
F TY (age 5+)		0.23	0.23
F TY retro bias adj.		0.43	
TY age 1 (millions)		7.334	7.334
TY age 1 retro bias adj.		5.132	
rho F		-0.46	
rho SSB		0.68	
rho rct		0.43	

Added 9/14/2015

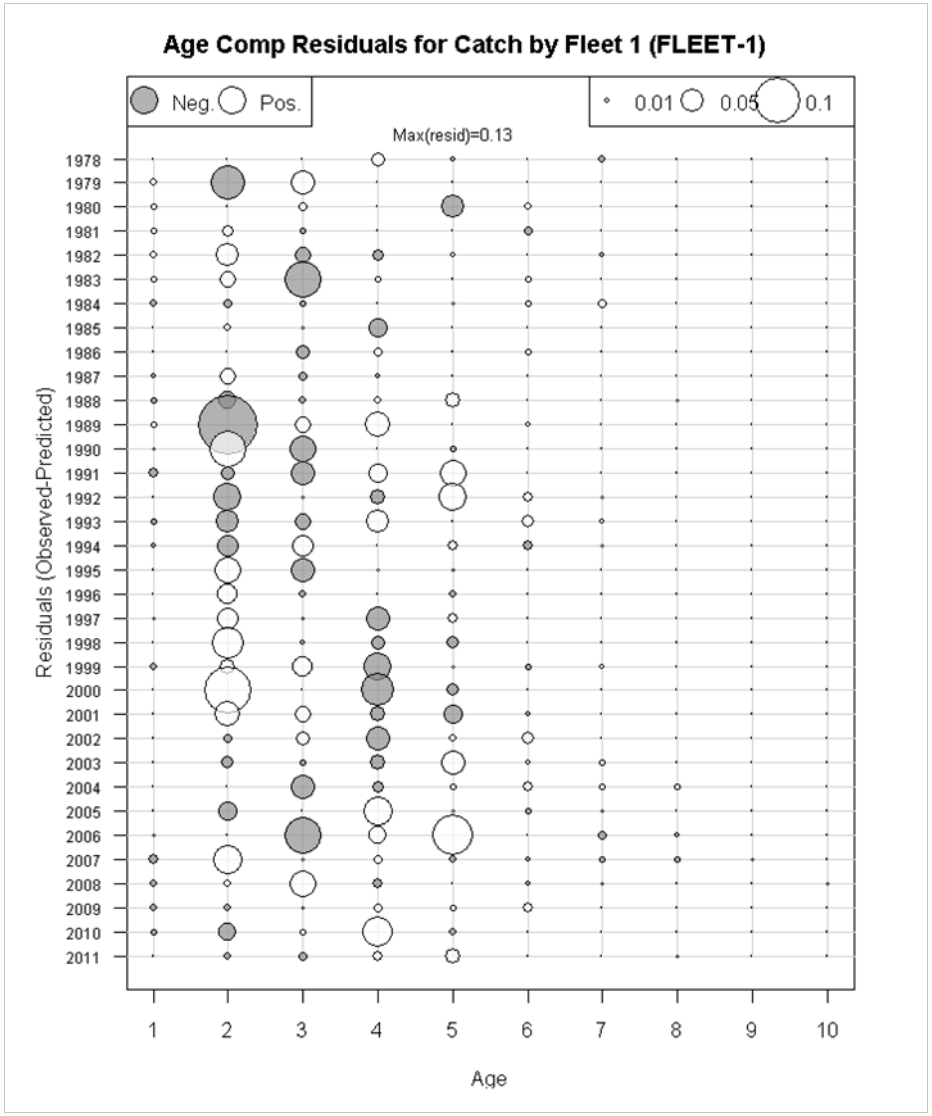
2012 ASAP



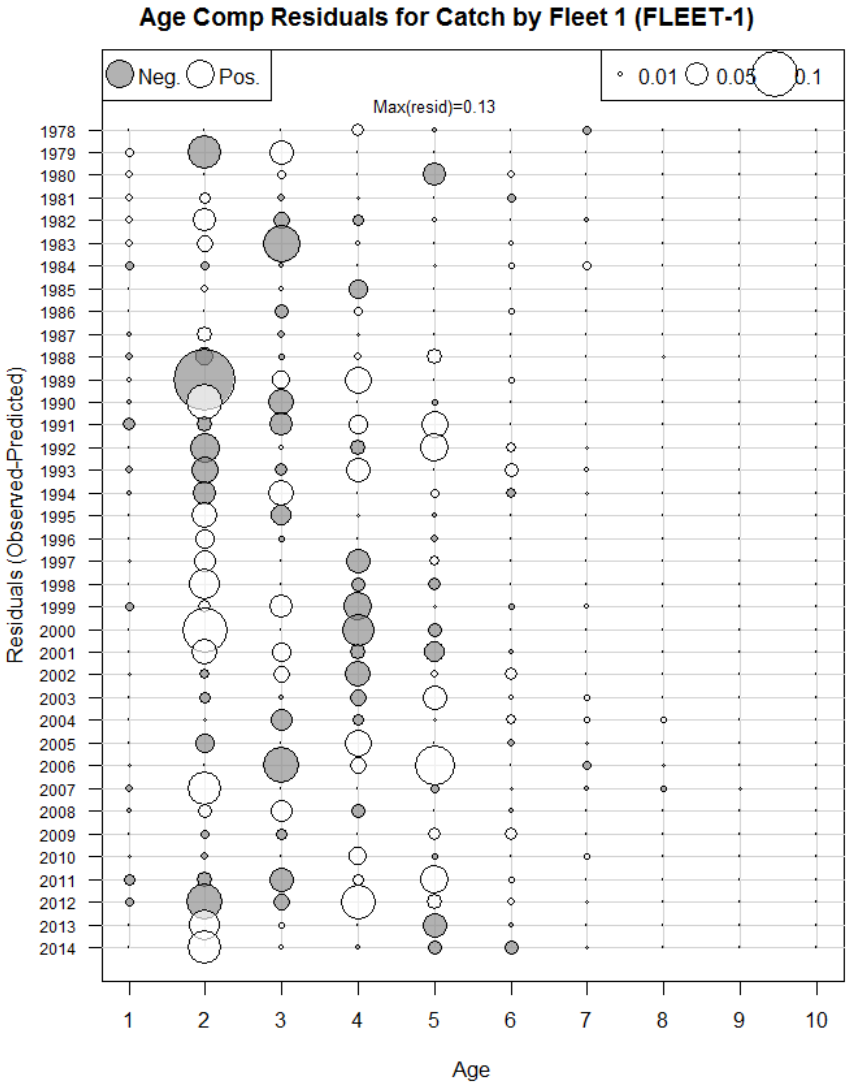
2015 ASAP



2012 ASAP



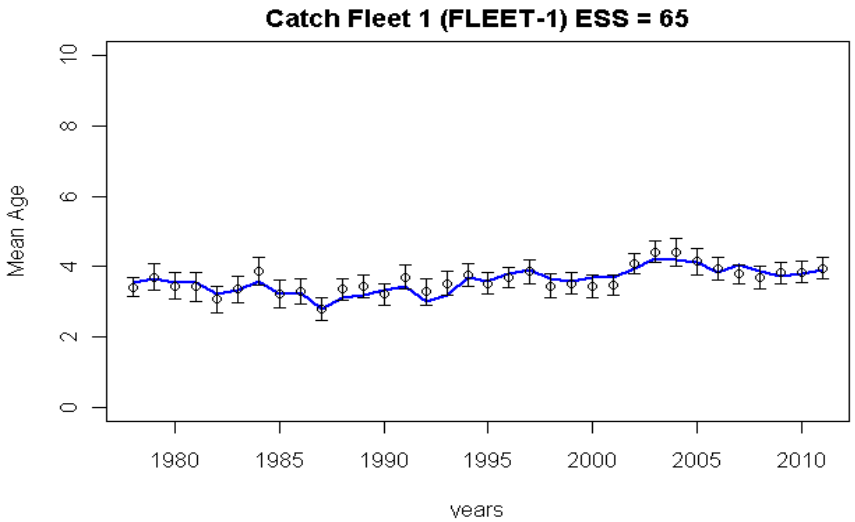
2015 ASAP

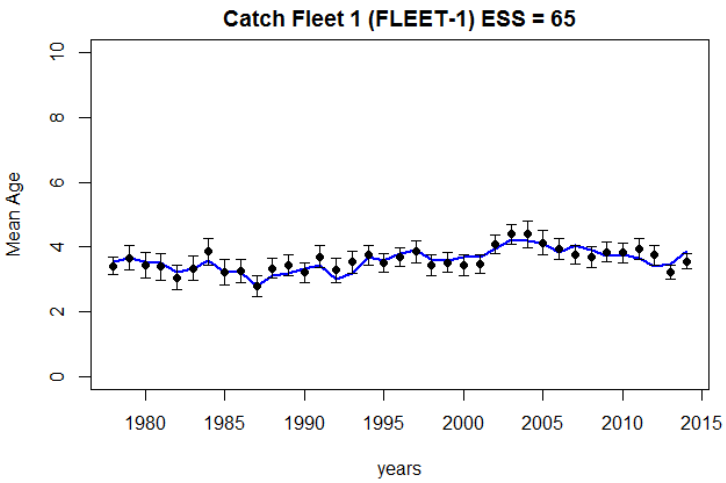


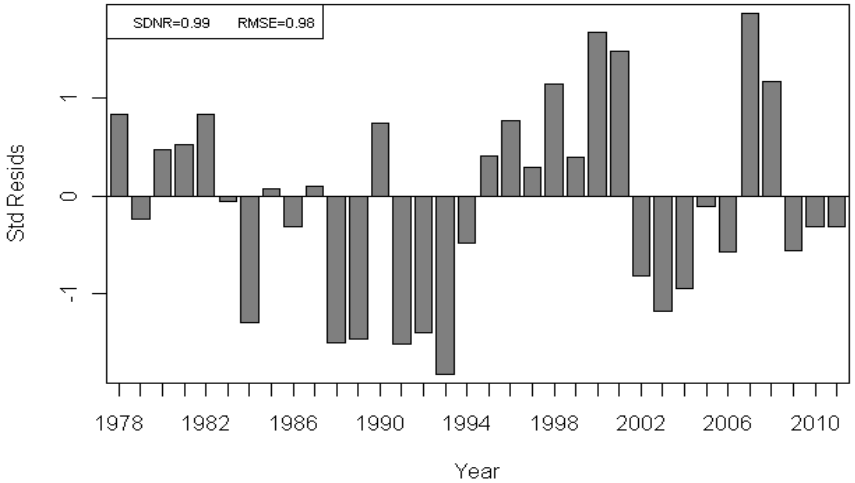
2012 ASAP

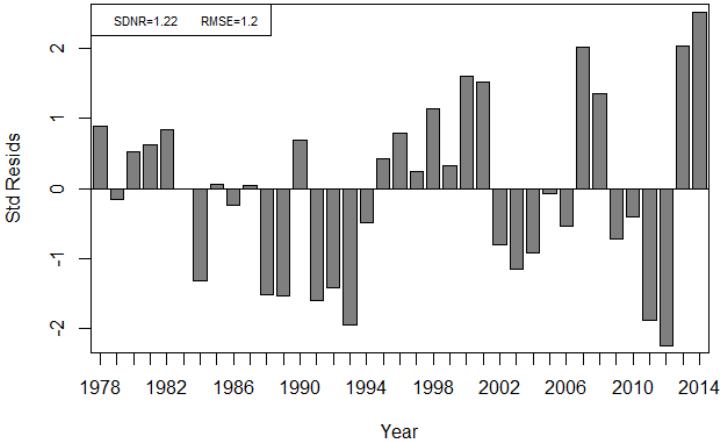
2015 ASAP

Model predicted mean age (blue line) and obs. mean



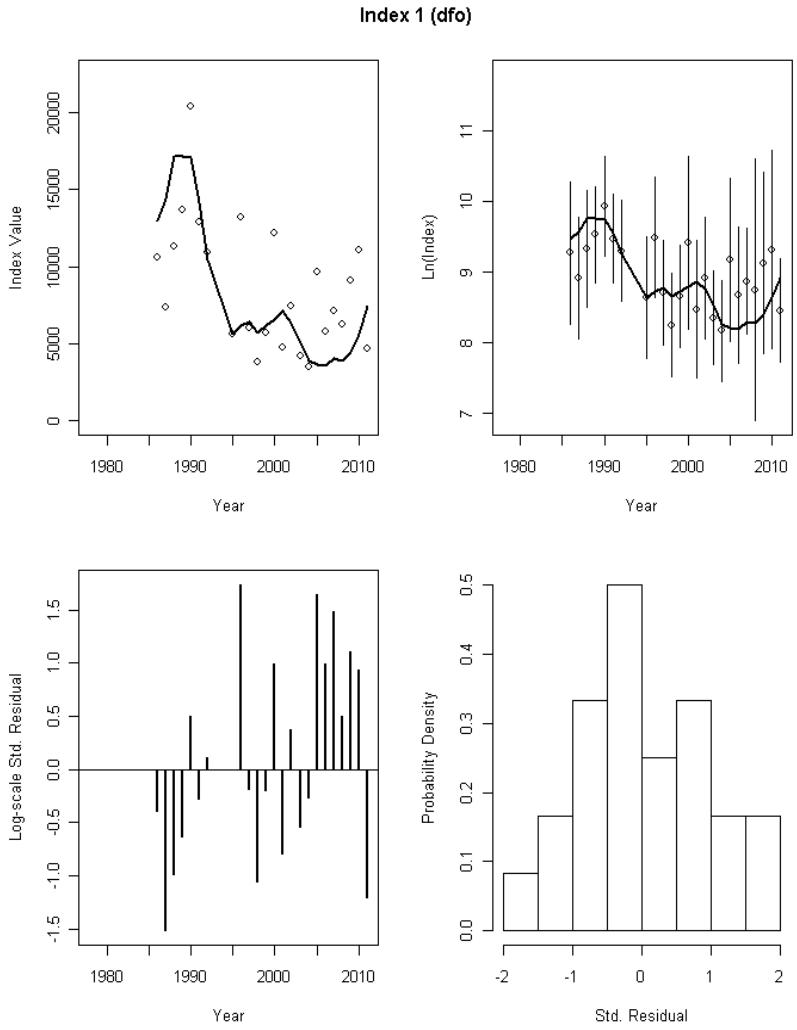




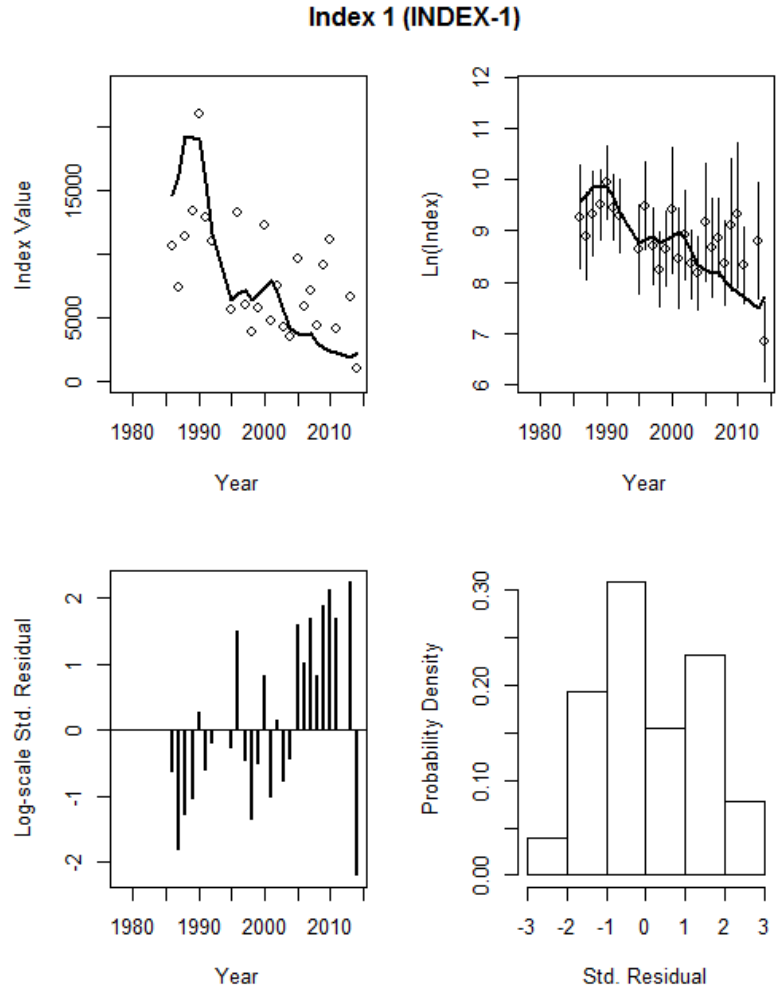


Residuals about the mean

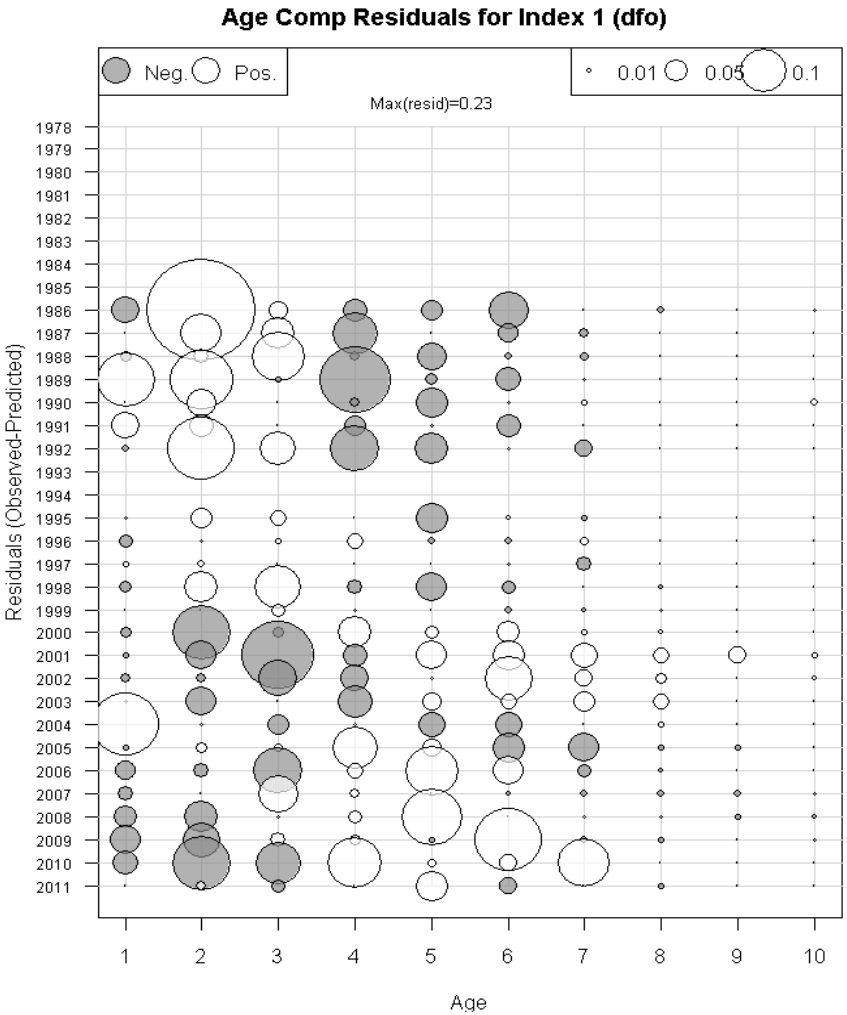
2012 ASAP



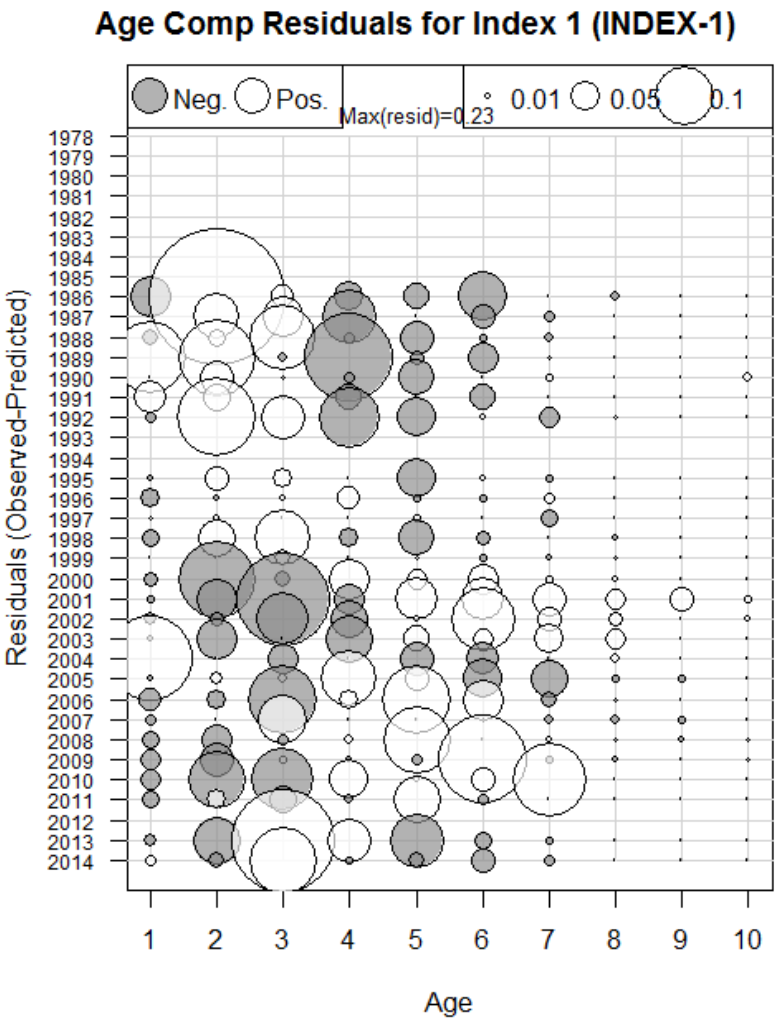
2015 ASAP



2012 ASAP



2015 ASAP



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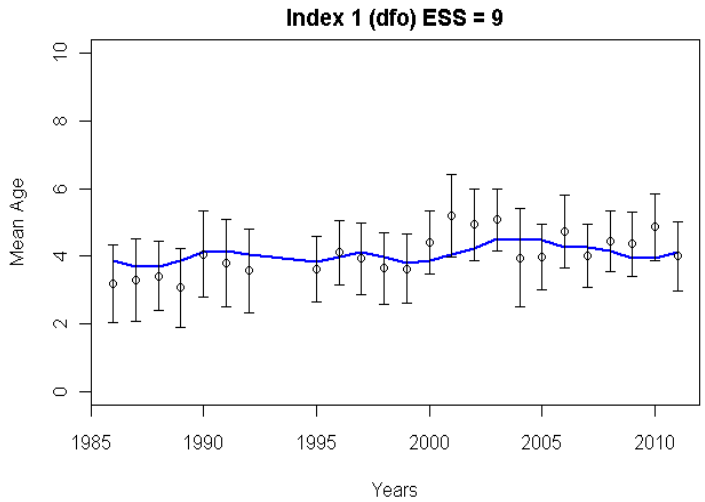
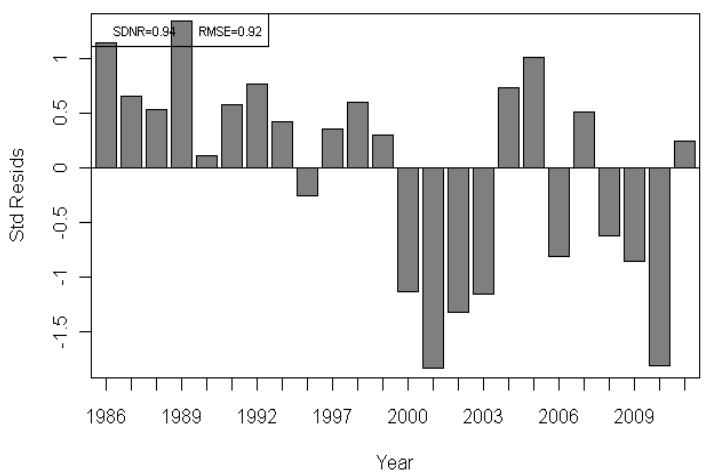
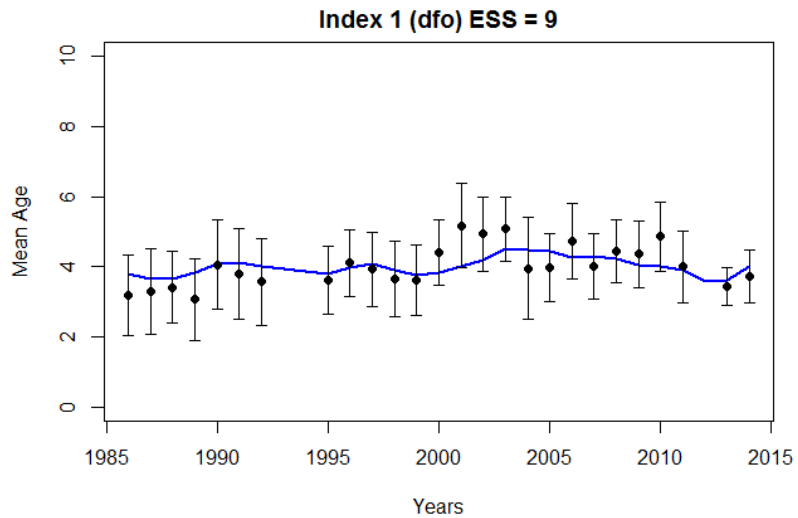
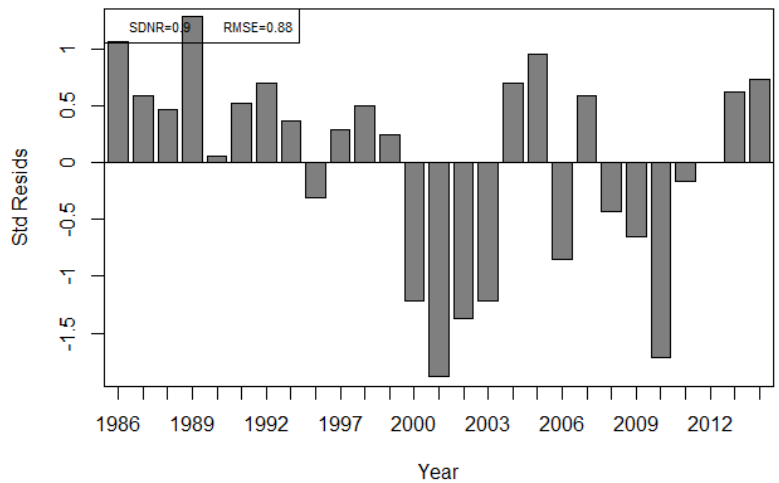


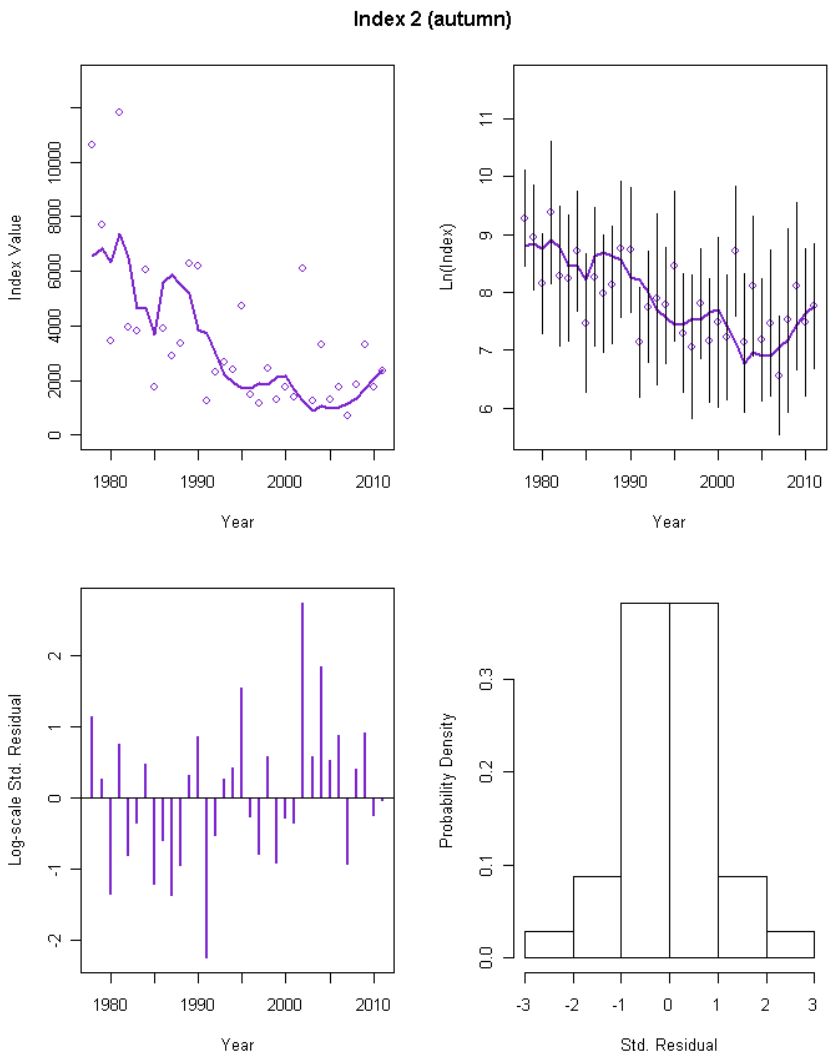


2015 ASAP

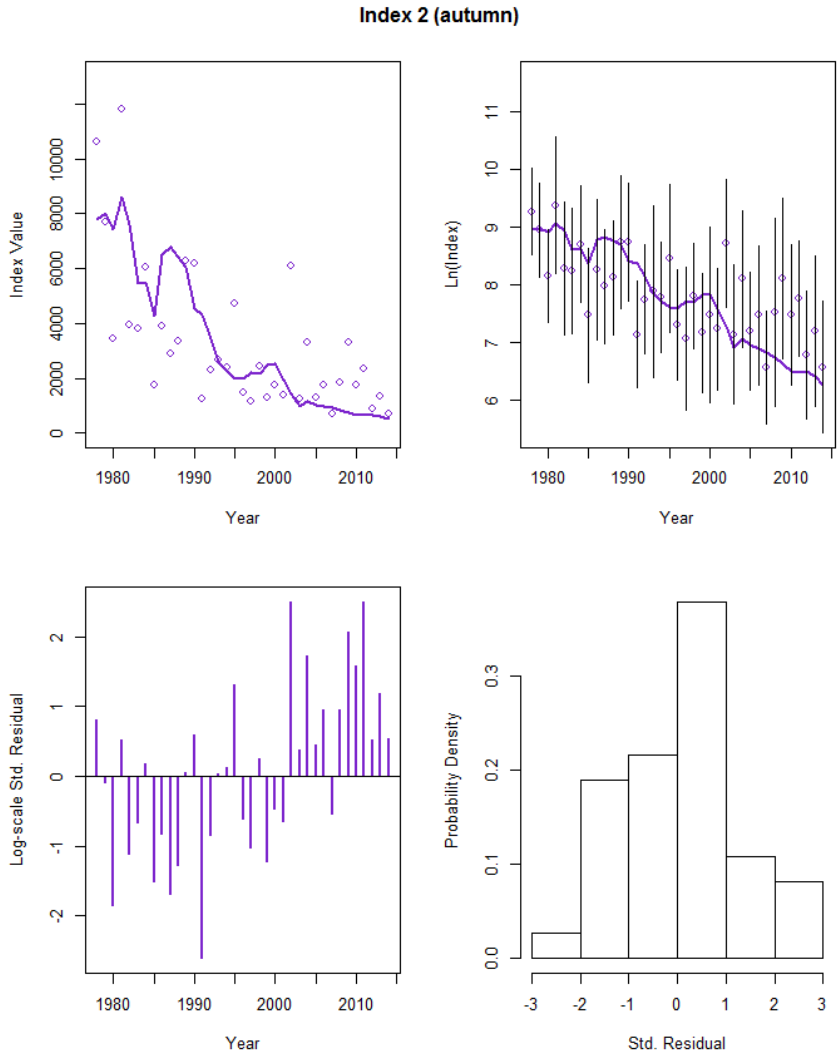




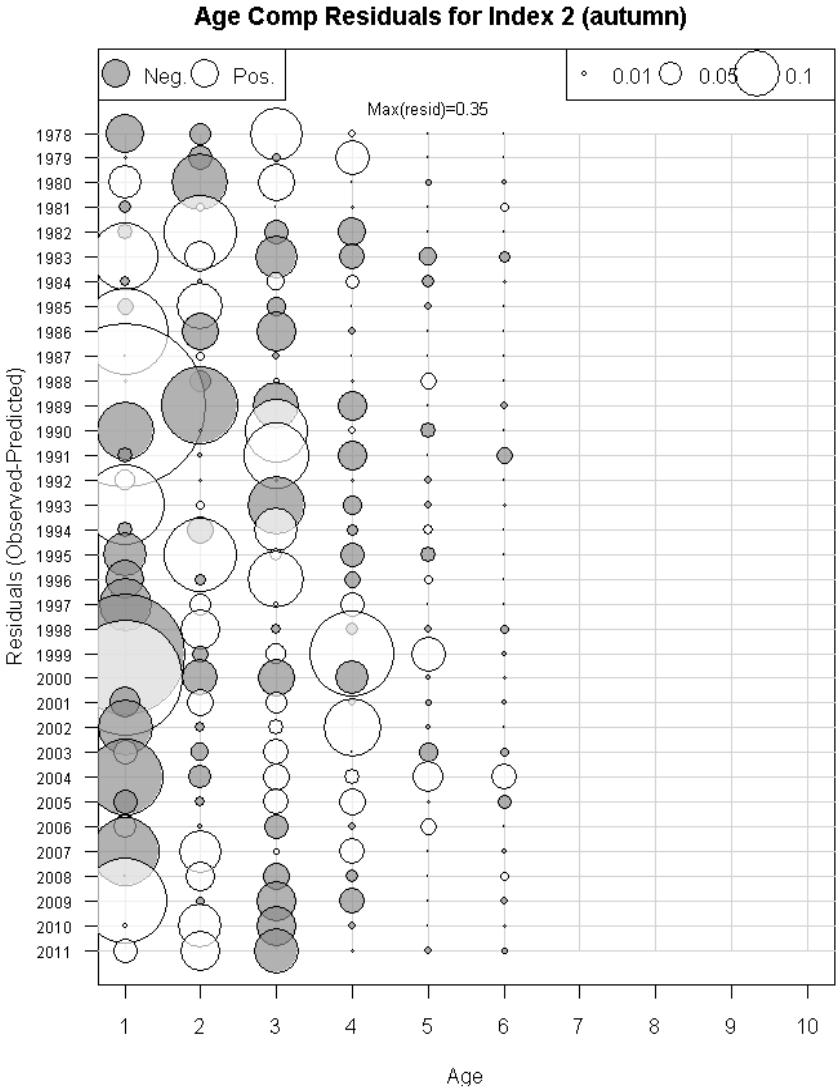
2012 ASAP



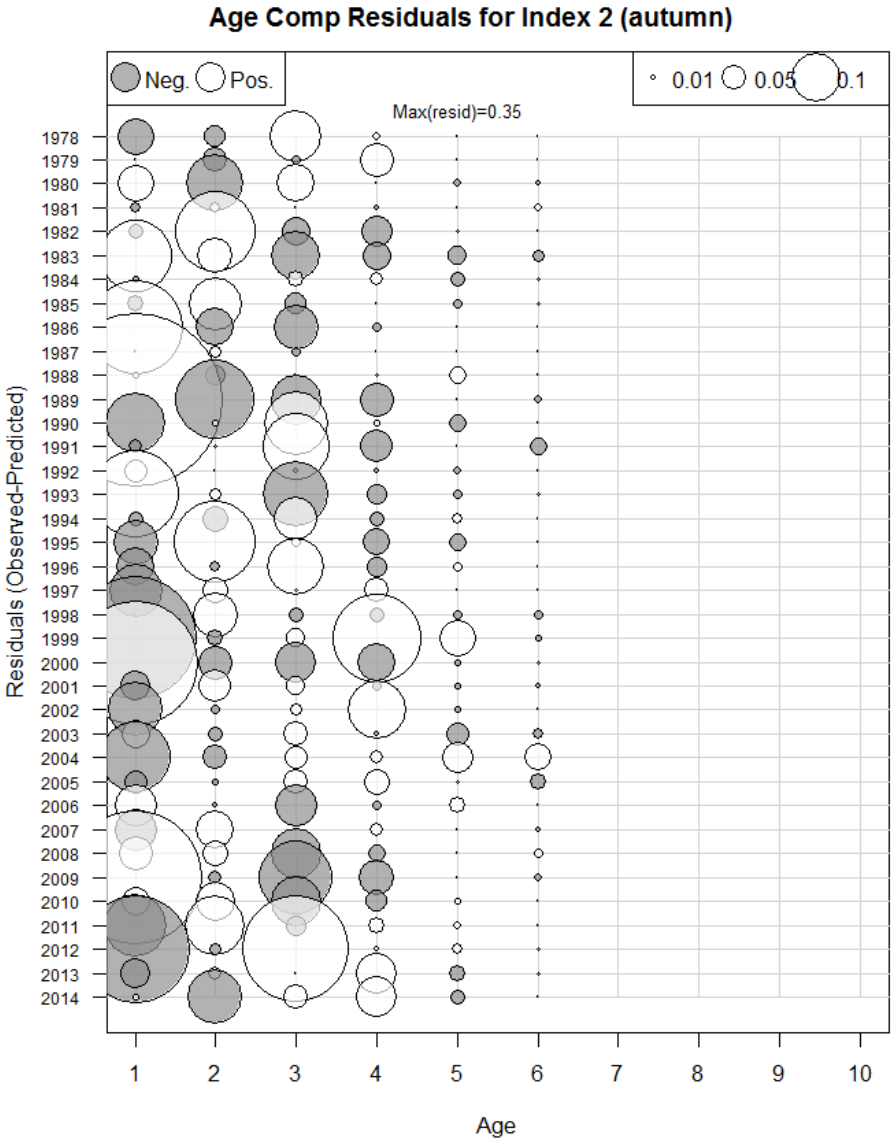
2015 ASAP



2012 ASAP



2015 ASAP



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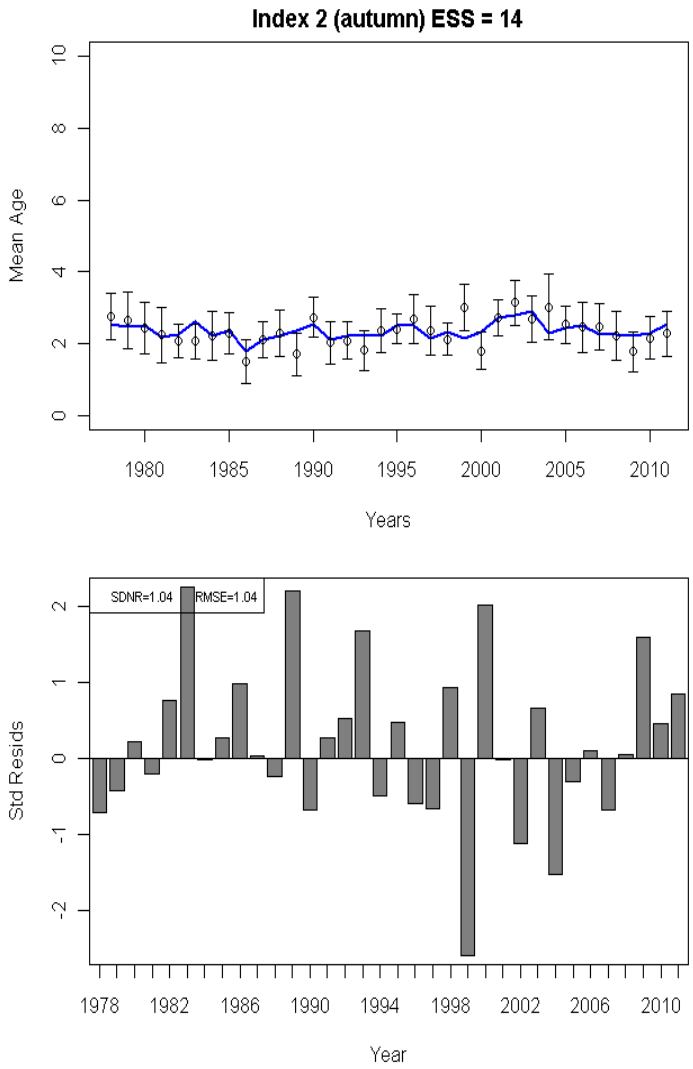

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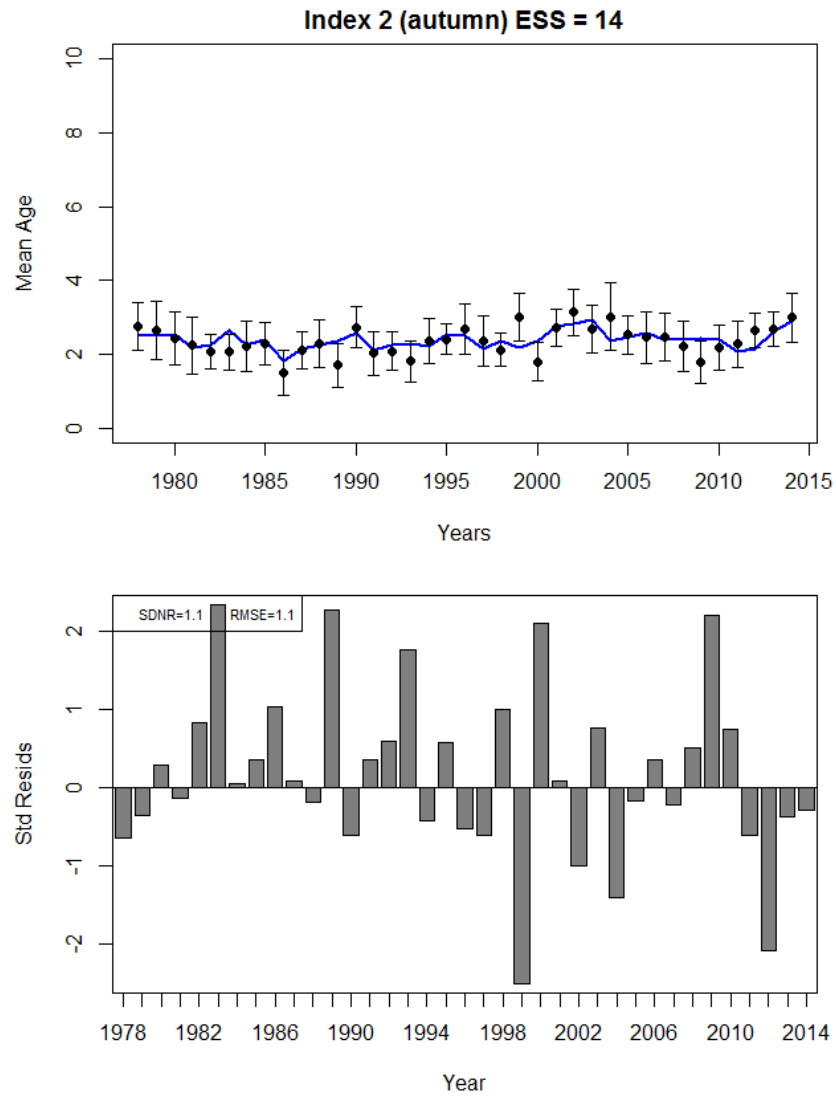

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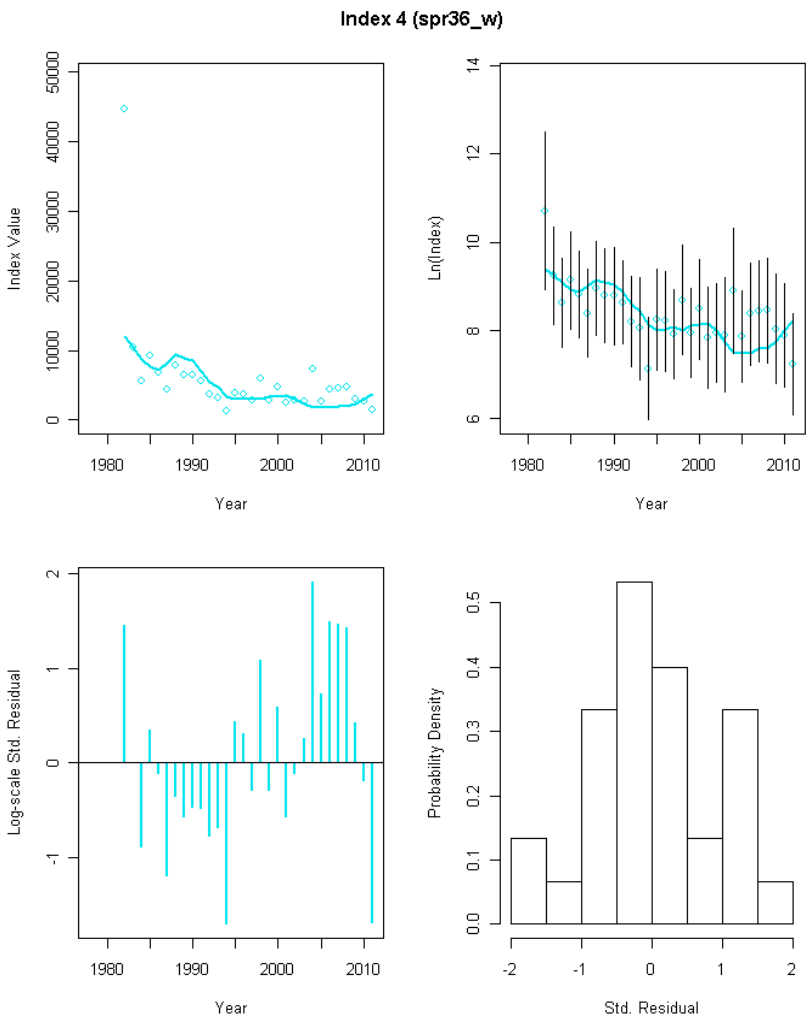
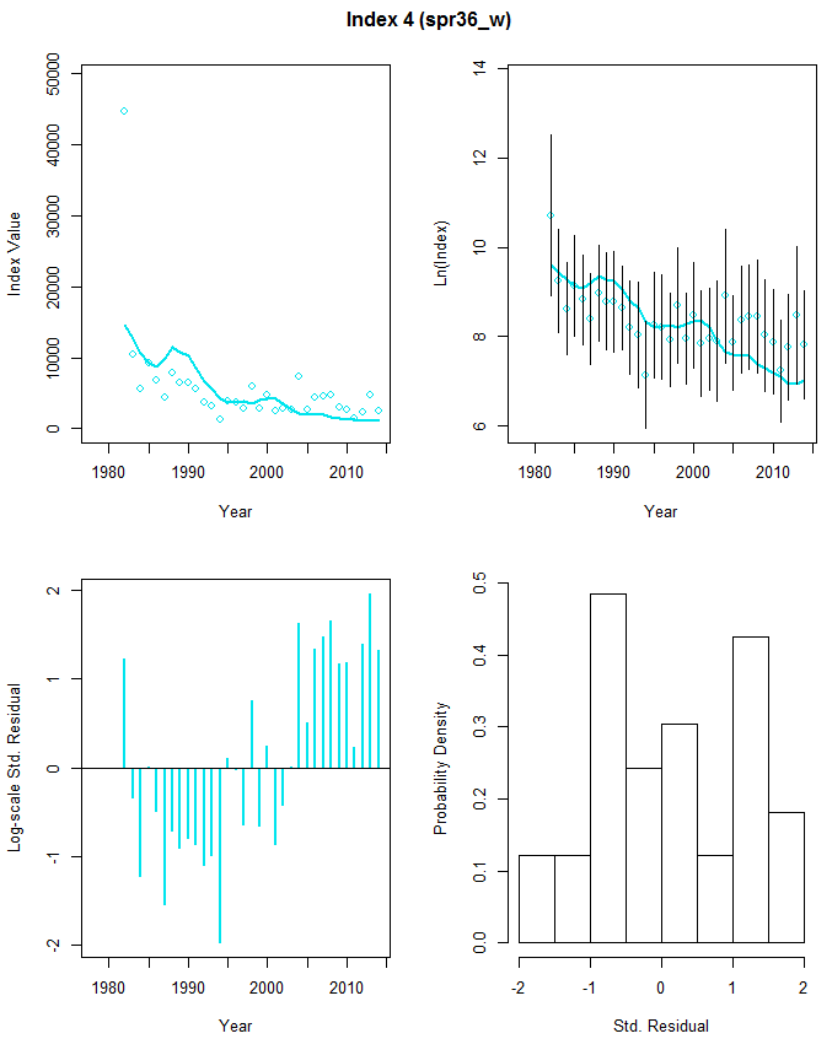
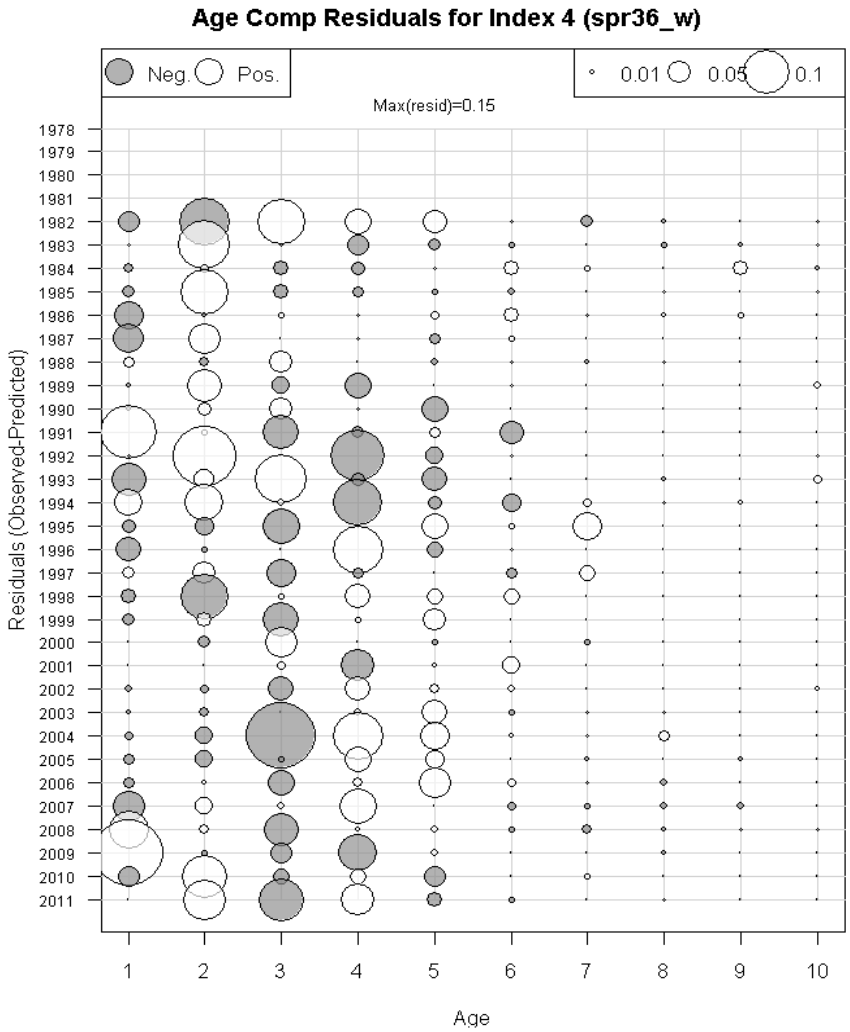


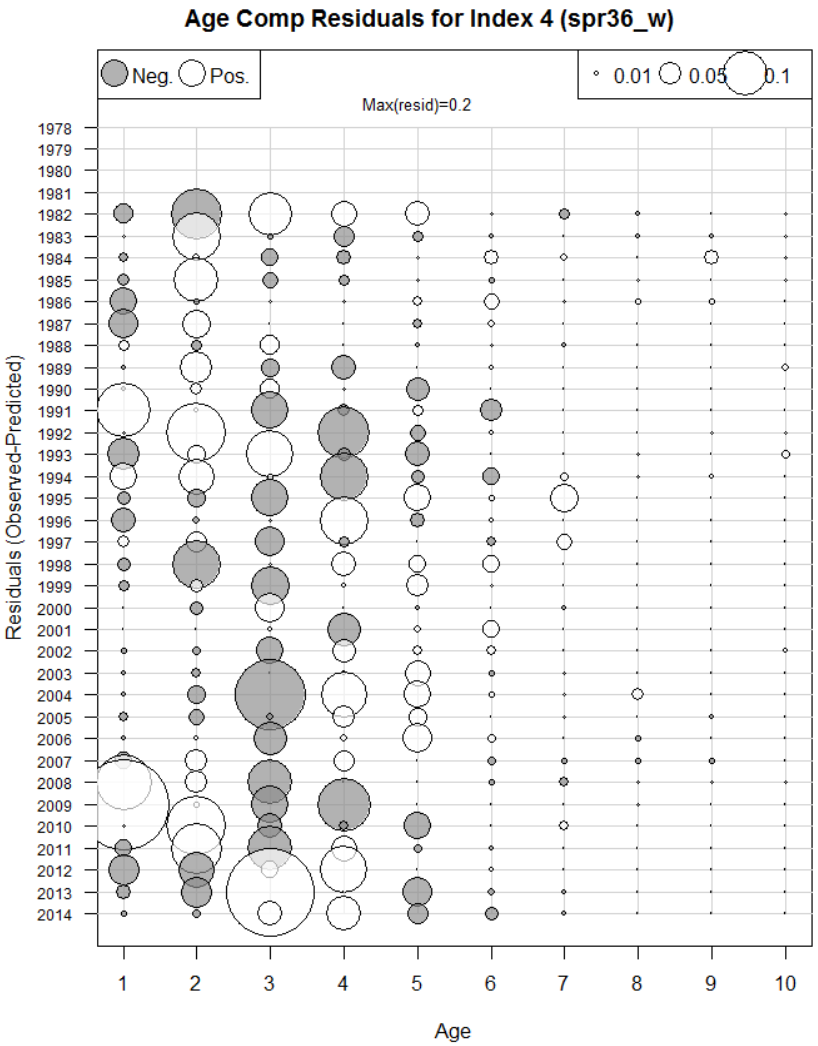
2015 ASAP



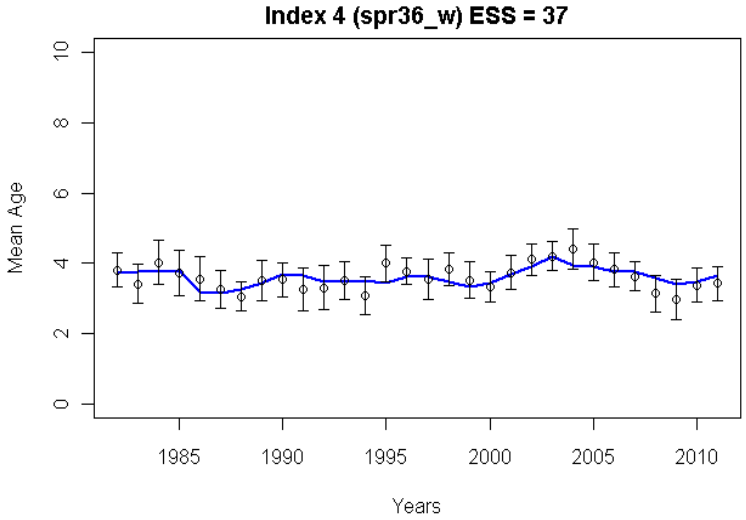
2012 ASAP

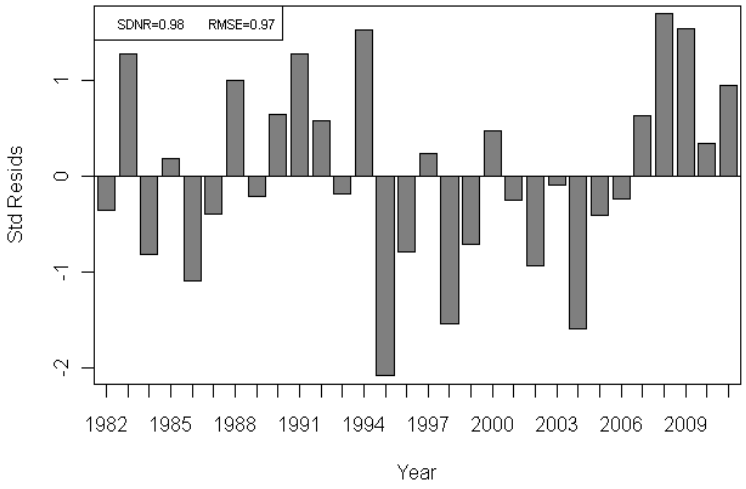


2015 ASAP

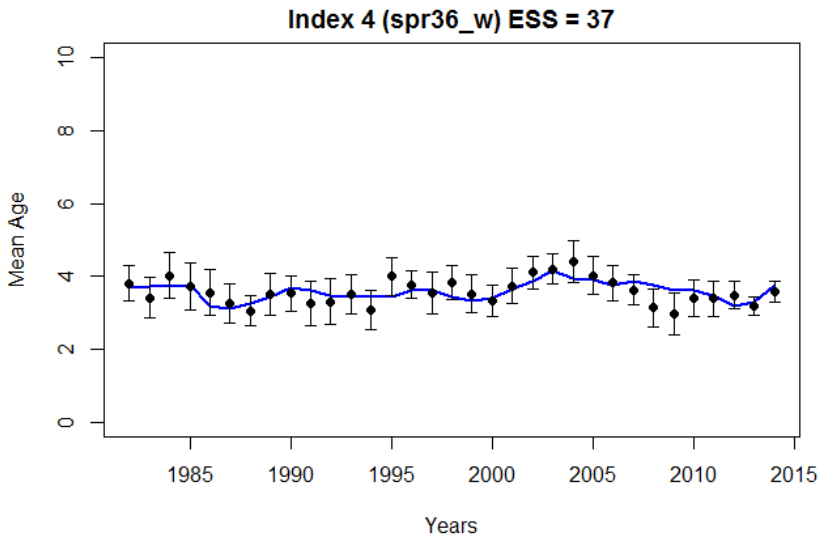


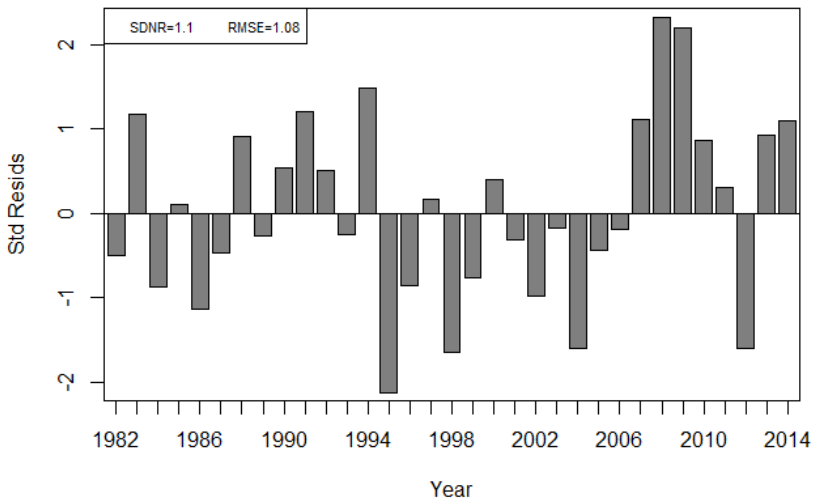
2012 ASAP



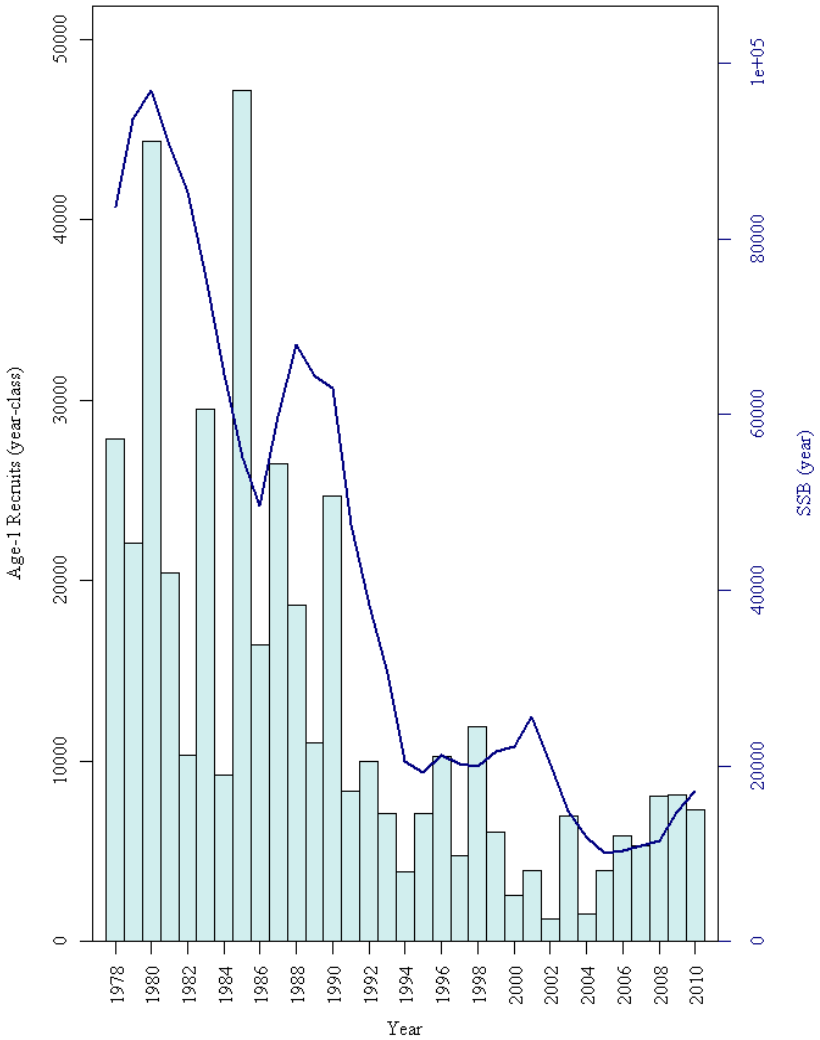


2015 ASAP

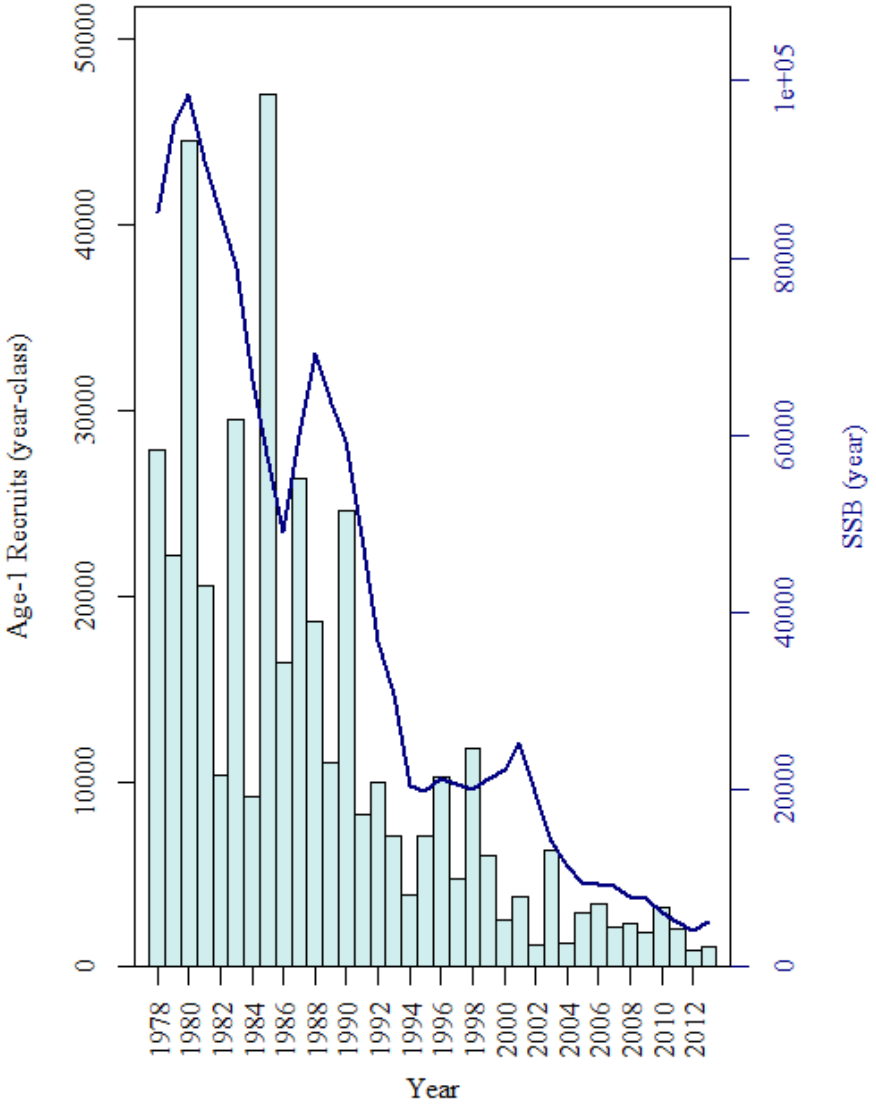




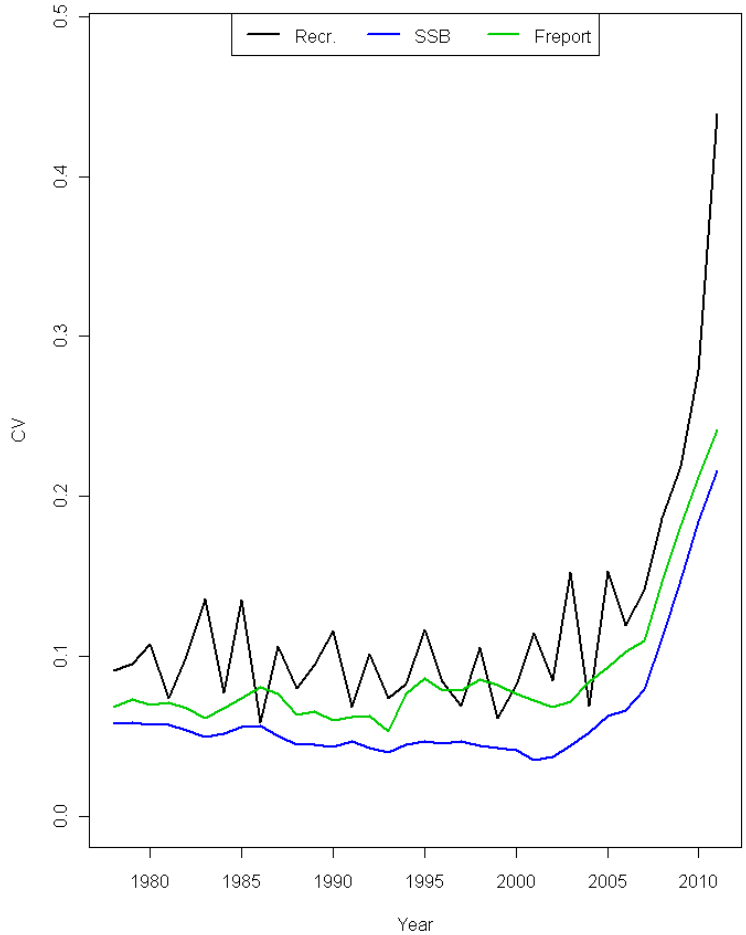
2012 ASAP



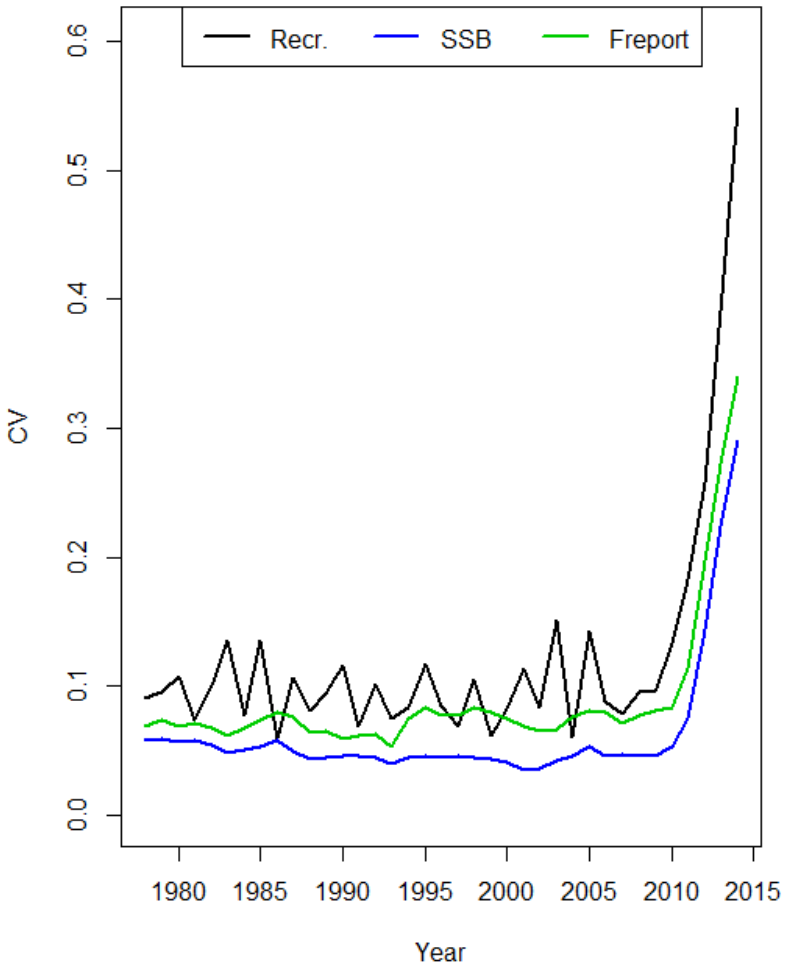
2015 ASAP



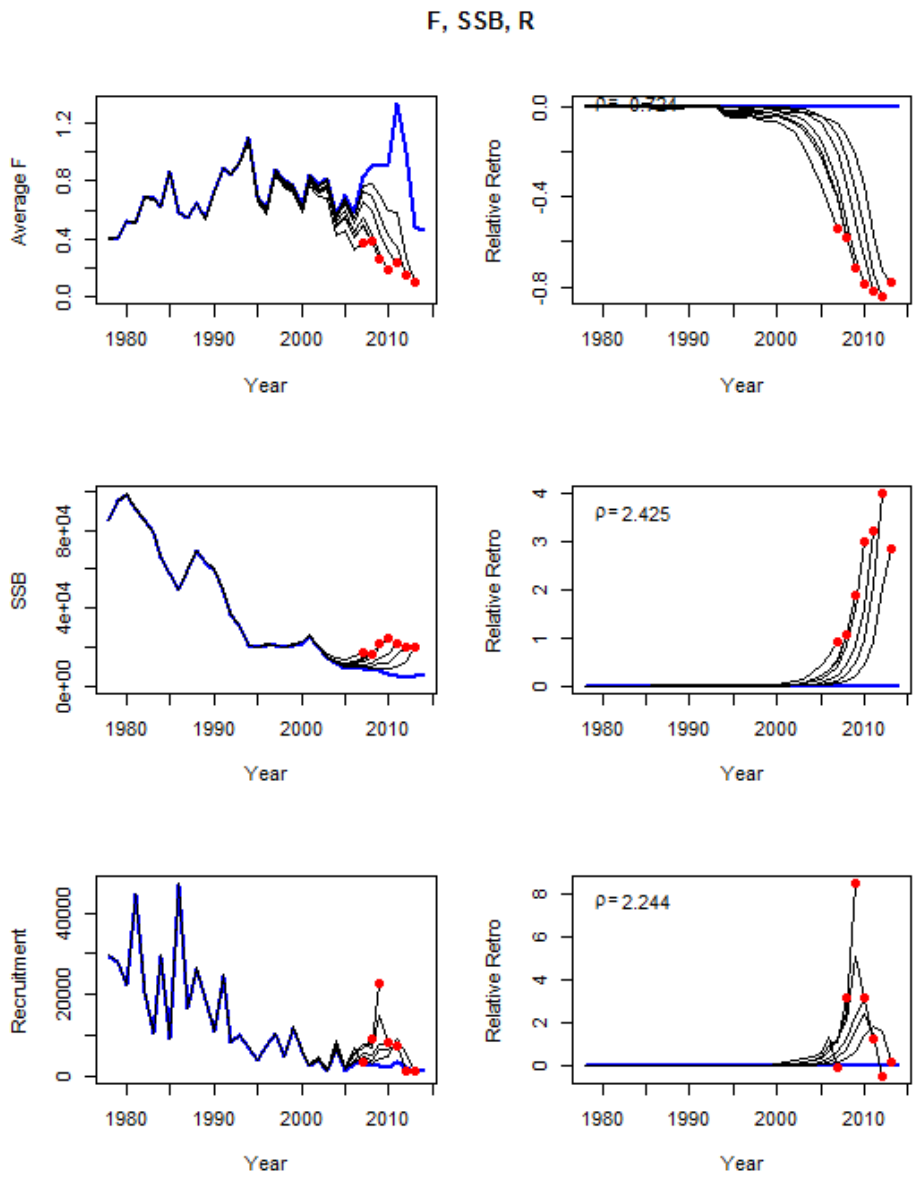
2012 ASAP



2015 ASAP



Retrospective Analysis



Removing DFO 2012
Increased retro slightly

YPR/Projection inputs

M = 0.2 ; 5-yr mean (2010-2014), maturity(2011-2015)

Age	ASAP selectivity	Stock weight	Catch weight	Spawning stock weight	Proportion mature
1	0.01	0.285	0.489	0.285	0.02
2	0.11	0.849	1.390	0.849	0.32
3	0.50	1.679	2.180	1.679	0.90
4	0.89	2.446	2.748	2.446	0.99
5	0.98	3.257	3.660	3.257	1.00
6	1.00	4.151	4.535	4.151	1.00
7	1.00	4.777	5.116	4.777	1.00
8	1.00	5.809	6.276	5.809	1.00
9	1.00	7.519	9.005	7.519	1.00
10	1.00	13.045	13.045	13.045	1.00

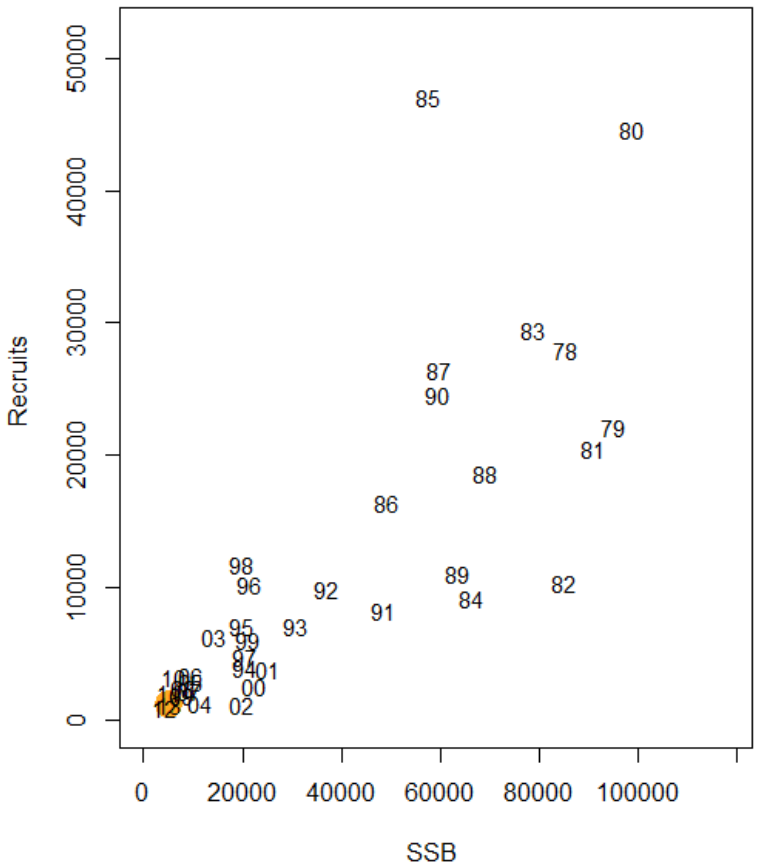
Base ASAP: Biological Reference Points (M=0.2)

Long term projection at F40% to derive MSY BRPs

2-stage empirical CDF of recruitment; 50,000 mt SSB cut point

1st stage – low recruitment: 5.399 million

2nd stage –high recruitment: 24.337 million



Biological Reference Points (M=0.2)

YPR and
MSY BRPs from long-term projection at F40%

Model	F40%	Y/R	SSB / R	Recruitment	SSBmsy	MSY
YPR	0.169	1.28	8.45	12,573	106,285	16,138
100 yr Projection				12,083	201,152	30,569

Since 2012:
Decrease in F40% , increase in SSBmsy

Short term projections

Two stage Empirical model

Year	5%	SSB	95%
2015	539	1,522	3,192
2016	152	932	2,508
2017	787	2,134	6,250
2018	3,054	7,001	24,931
	5%	**F**	**95%**
2015	0.00	1.51	5.00
2016	0.169	0.169	0.169
2017	0.169	0.169	0.169
2018	0.169	0.169	0.169
	5%	**Catch**	**95%**
2015	1	1,784	1,784
2016	19	135	377
2017	87	263	679
2018	351	799	2,794

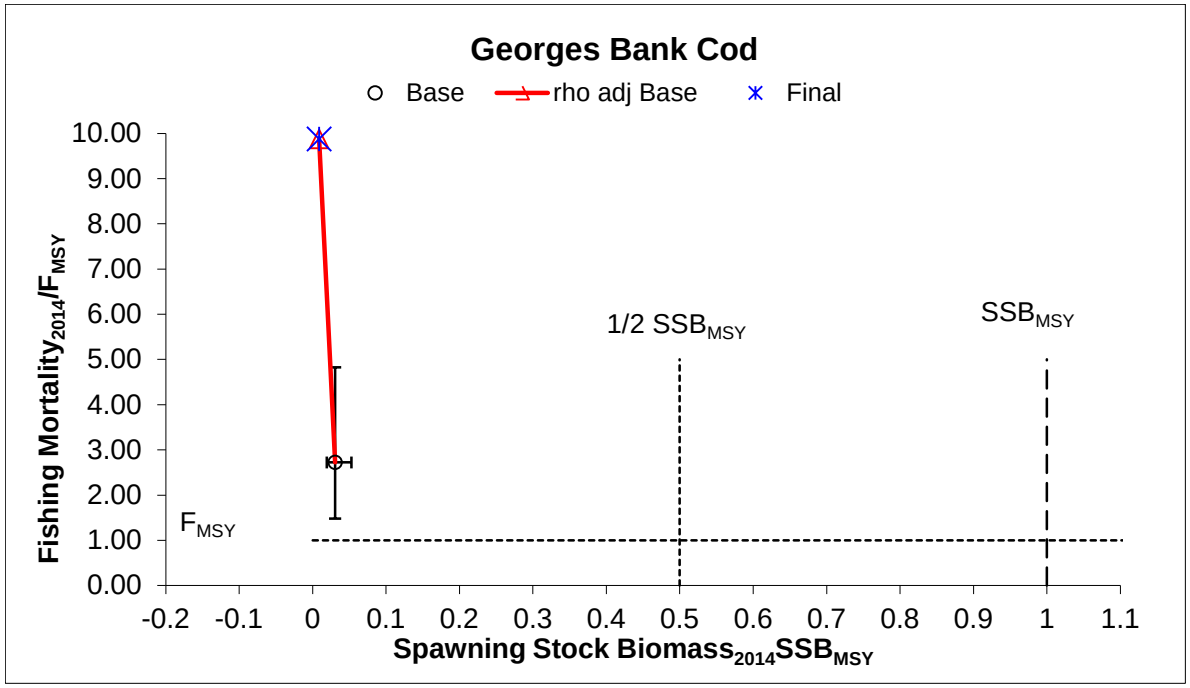
Empirical model 10 years recent rct.

Year	5%	SSB	95%
2015	539	1,522	3,192
2016	136	908	2,469
2017	600	1,473	2,924
2018	2,233	3,746	6,262
	5%	**F**	**95%**
2015	0.00	1.51	5.00
2016	0.169	0.169	0.169
2017	0.169	0.169	0.169
2018	0.169	0.169	0.169
	5%	**Catch**	**95%**
2015	1	1,784	1,784
2016	17	132	375
2017	65	192	425
2018	258	448	757

SSB	Avg. Rct
SSB < 50K	5.399
SSB > 50 K	24.337
34 yr	12.083
10 yr, recent	2.697

Applying 2-stage rct. model provides overly optimistic catch advice, given recent SSB

Georges Bank Cod Stock Status



Stock status : overfished, SSB < ½ B_{MSY}

overfishing is occurring, F > F_{MSY}

Uncertainties and research needs

- **Estimates of catch and natural mortality**
  - **Historically and currently**
- **DFO survey: not all strata sampled every year**
- **Changes in growth**
  - **Affects fecundity , egg viability, larval/juvenile survival to age 1**

Summary - Re- cap

- Recent survey indices continue to be among the lowest in time series
- Mean length at age declining on 3 + fish since 1985 (affects rct)
- Continued truncated age structure in surveys and fishery (2014 1st year CA did not land any age 9 or 10+ fish)

- ASAP update diagnostics similar to 2012 benchmark within fleet and surveys, however, model fit to surveys more uncertain
- Other model formulations could be explored (e.g. set rec. dev. = 1 and change recruitment CV, increase CV on catch)
- Above is outside the ToR for this operational update.

- Stock has been overfished for entire time series: 37 years
- 34 yr avg. rct = 12.1 M age 1 fish; 1990 yc last above avg YC ~ 25 yrs ago
- Last estimate of SSB > 50K was 1990

- 2-stage empirical rct. model in projections too optimistic, particularly in recent years, could be ~ 50% too high
- eGB model formulations since 2005 have overest. popn# relative to GB model

- 2015 status : GB cod stock is overfished and overfishing is occurring.

Questions ?

Homework

Year	spr_swpt_m	aut_swpt_mt	dfo_swpt_mt	spr_dfo_avg	sprdfo_aut
1983	32081.3679	10100.85509		32081.36786	21091.111
1984	20842.6982	13671.09643		20842.69821	17256.897
1985	29636.6464	4249.465714		29636.64643	16943.056
1986	22792.0821	5073.835179	25599.11864	24195.60039	14634.718
1987	13567.5346	6041.956339	18453.17657	16010.35556	11026.156
1988	18401.5286	7650.423482	29622.17852	24011.85354	15831.139
1989	14949.3295	6435.917679	30370.49344	22659.91145	14547.915
1990	16042.733	15754.21875	74652.76094	45347.74699	30550.983
1991	12205.3428	1943.851339	42745.91784	27475.6303	14709.741
1992	10165.279	4035.211071	31125.11282	20645.19592	12340.203
1993	9512.73402	2969.716339	38401.6961	23957.21506	13463.466
1994	1653.0967	4450.059643	23385.00286	12519.04978	8484.5547
1995	11438.1707	7686.091607	12707.82776	12072.99924	9879.5454
1996	10249.429	3702.340446	38868.19348	24558.81125	14130.576
1997	7122.73741	2587.107054	16252.04513	11687.39127	7137.2492
1998	15916.3714	3851.132946	8262.441349	12089.40639	7970.2697
1999	6377.62741	4111.970625	12243.47613	9310.551771	6711.2612
2000	11231.5934	1846.600714	36627.32599	23929.45969	12888.03
2001	7475.94884	2859.488036	19847.2726	13661.61072	8260.5494
2002	6886.62563	15397.5375	27703.25771	17294.94167	16346.24
2003	5730.1642	2859.57	14656.18595	10193.17507	6526.3725
2004	19569.7929	8047.116964	9024.681042	14297.23695	11172.177
2005	6204.23196	2146.671964	20067.6638	13135.94788	7641.3099
2006	8284.82705	3613.258929	15703.81444	11994.32074	7803.7898
2007	6918.45509	1515.123482	16613.42206	11765.93857	6640.531
2008	5892.4808	3938.6025	14398.50581	10145.4933	7042.0479
2009	4762.81487	5764.930714	27435.26151	16099.03819	10931.984
2010	5159.1682	3386.928214	42966.37522	24062.77171	13724.85
2011	2530.56536	4137.393214	9284.778554	5907.671956	5022.5326
2012	4755.31923	2201.2875	4652.793381	4704.056306	3452.6719
2013	7812.35896	2722.0995	10992.46692	9402.41294	6062.2562
2014	4808.26953	1852.761696	2662.274401	3735.271964	2794.0168
2015	2003.58008	0	8172.567948	5088.074014	2544.037

Swept area biomass (mt)

Averaged as

[((spr +dfo)/2) + autumn)] / 2

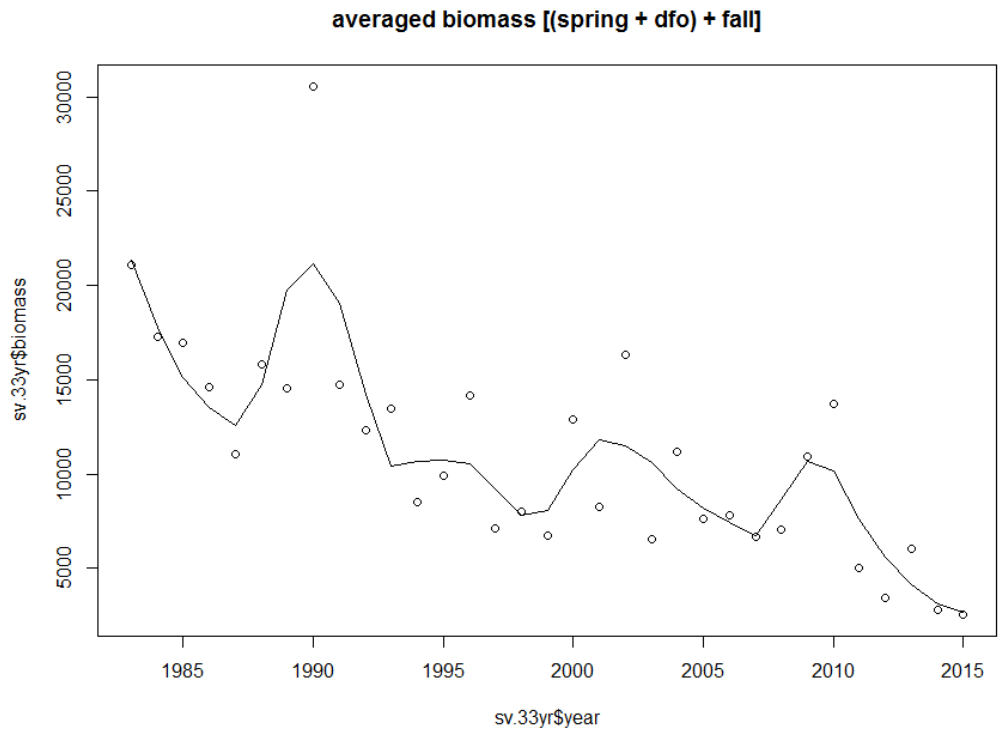
to account for seasonal effects

DFO SV did not survey entire Bank during 2006-2015.

1993, 1994, 2012 DFO surveys excluded from ASAP, and 2015 would be too in the future

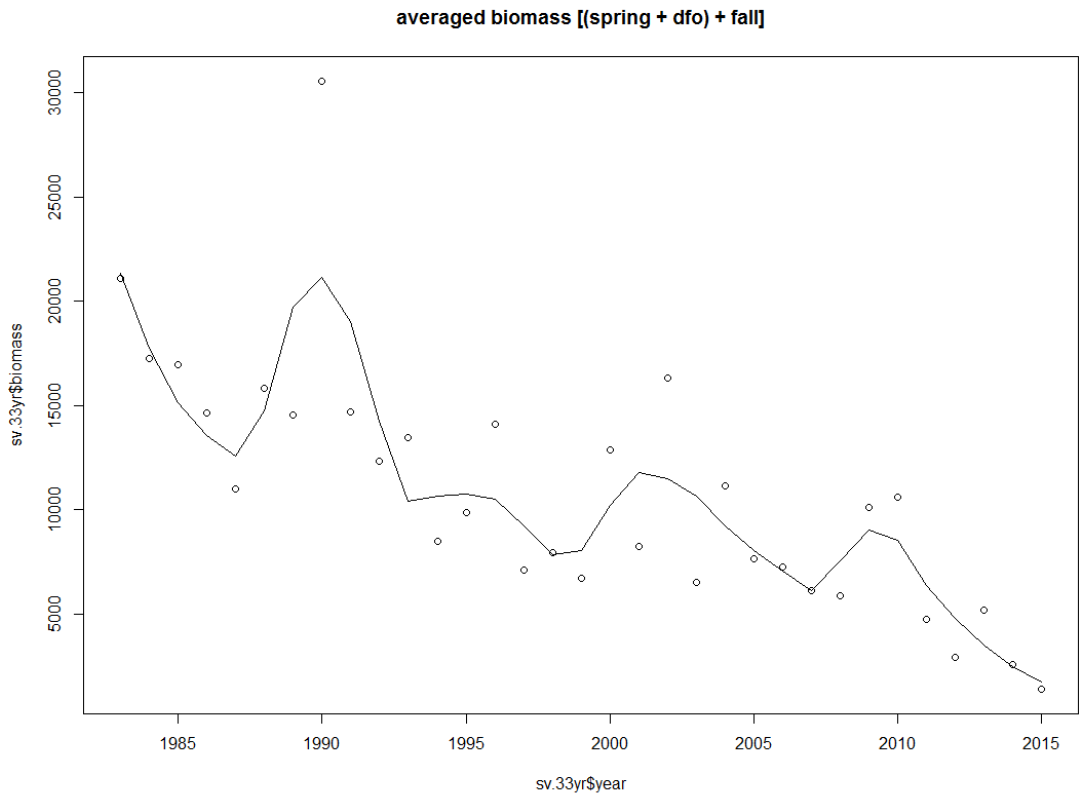
1983	21091.11
1984	17256.9
1985	16943.06
1986	14634.72
1987	11026.16
1988	15831.14
1989	14547.91
1990	30550.98
1991	14709.74
1992	12340.2
1993	13463.47
1994	8484.555
1995	9879.545
1996	14130.58
1997	7137.249
1998	7970.27
1999	6711.261
2000	12888.03
2001	8260.549
2002	16346.24
2003	6526.373
2004	11172.18
2005	7641.31
2006	7803.79
2007	6640.531
2008	7042.048
2009	10931.98
2010	13724.85
2011	5022.533
2012	3452.672
2013	6062.256
2014	2794.017
2015	2544.037

LOESS smooth on swept area biomass:
33 years, 0.3 span, 2 iterations : same as TRAC formulation



Year	sprdfo_aut
1983	21091.111
1984	17256.897
1985	16943.056
1986	14634.718
1987	11026.156
1988	15831.139
1989	14547.915
1990	30550.983
1991	14709.741
1992	12340.203
1993	13463.466
1994	8484.5547
1995	9879.5454
1996	14130.576
1997	7137.2492
1998	7970.2697
1999	6711.2612
2000	12888.03
2001	8260.5494
2002	16346.24
2003	6526.3725
2004	11172.177
2005	7641.3099
2006	7251.585
2007	6136.8672
2008	5912.18
2009	10100.238
2010	10596.414
2011	4741.0489
2012	2950.2863
2013	5199.6642
2014	2585.105
2015	1413.8381

LOESS smooth on swept area biomass:
33 years, 0.3 span, 2 iterations : same as TRAC formulation



DFO expanded
To sampled area only

Last 3 years regression of loess smooth :2013-2015

```
lm(formula = y.smooth.33[(length(y.smooth.33) - step.back):length(y.smooth.33)
 ~     seq(1:(step.back + 1)))

Residuals:
     1       2       3
  84.21 -168.42   84.21

Coefficients:
                                    Estimate     Std. Error    t value    Pr(>|t|)
(Intercept)                          4759.7      315.1  15.106    0.0421 *
Slope                                -727.0      145.9     -4.984   0.1260
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 206.3 on 1 degrees of freedom
Multiple R-squared:  0.9613,  Adjusted R-squared:  0.9226
F-statistic: 24.84 on 1 and 1 DF,  p-value: 0.126
```

Last 5 years regression of loess smooth 2011-2015

```
lm(formula = y.smooth.33[(length(y.smooth.33) - step.back):length(y.smooth.33)] ~
   seq(1:(step.back + 1)))

Residuals:
    1       2        3        4       5
 501.3  -244.2 -509.2   -254.1   506.3

Coefficients:
                          Estimate   Std. Error    t value     Pr(>|t|)
(Intercept)               8330.3     571.6         14.573      0.000701 ***
Slope                    -1234.8     172.4          7.164      0.005602 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 545 on 3 degrees of freedom
Multiple R-squared:  0.9448,  Adjusted R-squared:  0.9264
F-statistic: 51.32 on 1 and 3 DF,  p-value: 0.005602
```

Last 3 years regression of loess smooth :2013-2015 ; dfo expanded only to strata sampled

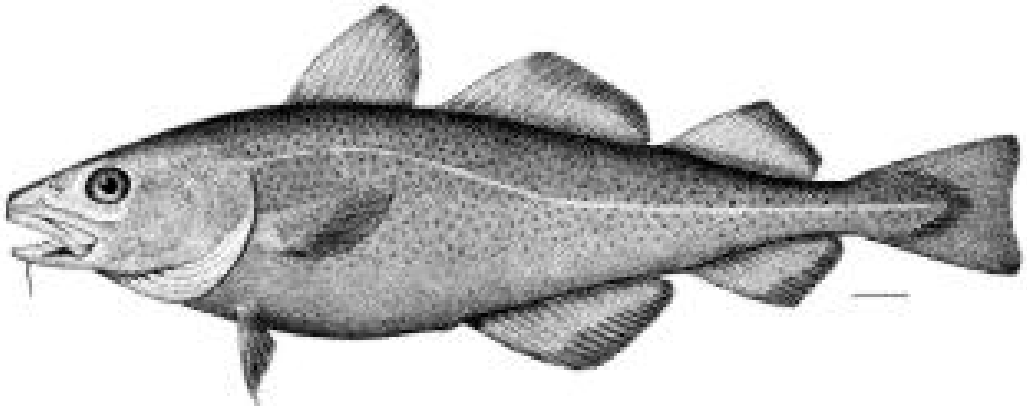
```
lm(formula = y.smooth.33[(length(y.smooth.33) - step.back):length(y.smooth.33)] ~
   seq(1:(step.back + 1)))

Residuals:
    1       2        3
 45.22   -90.45  45.22

Coefficients:
                                    Estimate    Std. Error   t value   Pr(>|t|)
(Intercept)                         4354.68     169.22       25.73     0.0247 *
Slope                               -884.33      78.33      -11.29      0.0562
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 110.8 on 1 degrees of freedom
Multiple R-squared:  0.9922,  Adjusted R-squared:  0.9844
F-statistic: 127.5 on 1 and 1 DF,  p-value: 0.05624
```

Predicted 2015 catch :

loess	intercept	slope		year	predicted loess		ratio	3 yr avg lnds	projected
3 yr	4759.7	-727	1	2013	4032.7		predicted	2186	2016 catch (mt)
			2	2014	3305.7				
			3	2015	2578.7				
			4	2016	1851.7		2016/2015	0.72	1570
			5	2017	1124.7				
5yr	8330.3	-1234.8	1	2013	7095.5				
			2	2014	5860.7				
			3	2015	4625.9				
			4	2016	3391.1		2016/2015	0.73	1603
			5	2017	2156.3				

DFO expanded to area sampled only									
loess	intercept	slope		year	predicted loess		ratio	3 yr avg lnds	projected
3 yr	4354.68	-884.33	1	2013	3470.35		predicted	2186	2016 catch (mt)
			2	2014	2586.02				
			3	2015	1701.69				
			4	2016	817.36		2016/2015	0.48	1050
			5	2017	-66.97