

Sandbar Shark Assessment State-space, Age-structured Production Model



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SEDAR-21 Review Workshop, April 18-22, 2011

OUTLINE

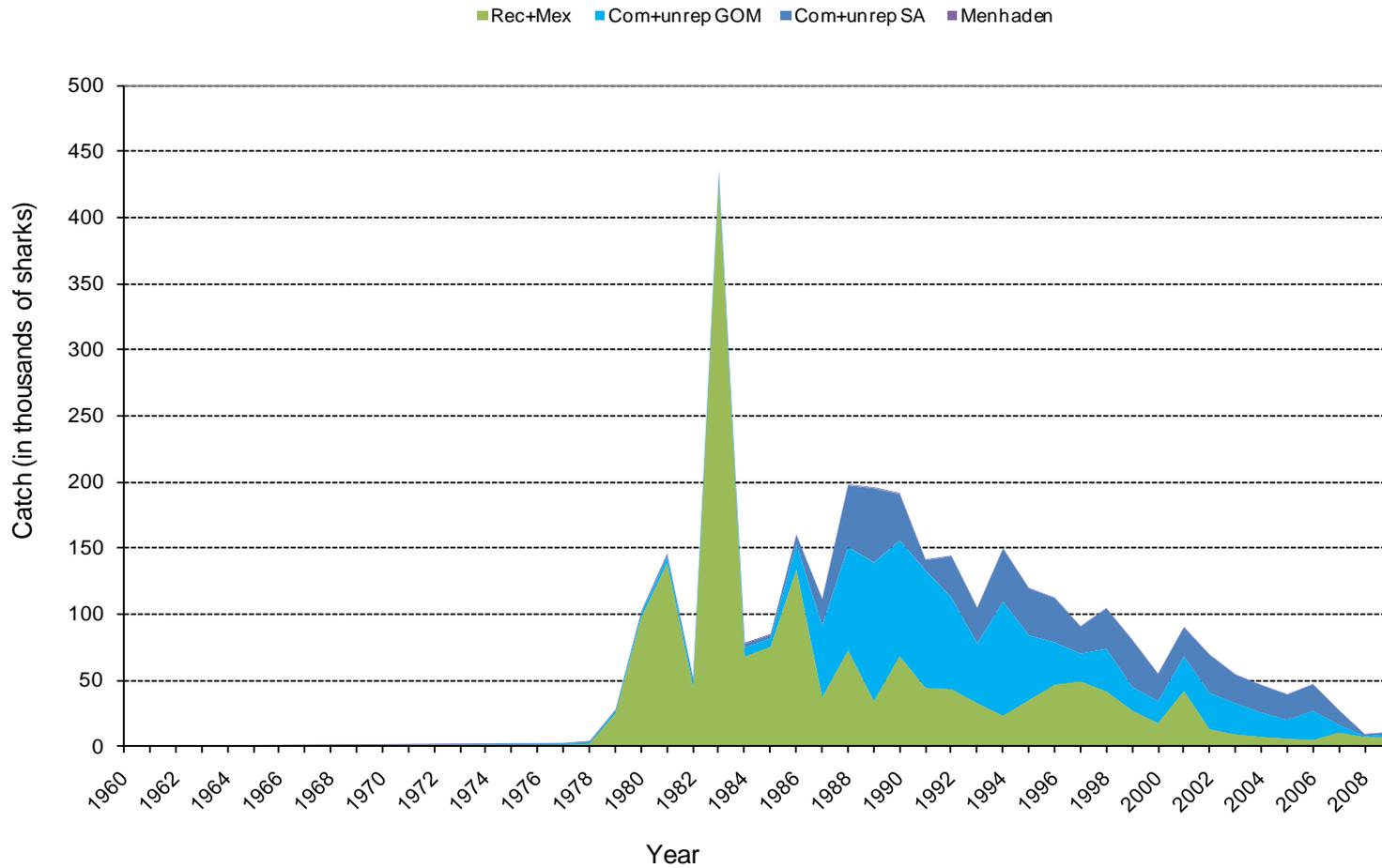
1. Data Inputs
 - a. Fishery
 - b. Biology
2. Model Description
3. Base Model and Results
4. Sensitivity analyses
5. Summary of all results
6. Continuity case
7. Retrospective analysis
8. Projections

1a. Fishery Inputs

- Catch Series:
 - Commercial + Unreported Commercial GOM
 - Commercial + Unreported Commercial ATL
 - Recreational + Mexican
 - Menhaden discard

Catches

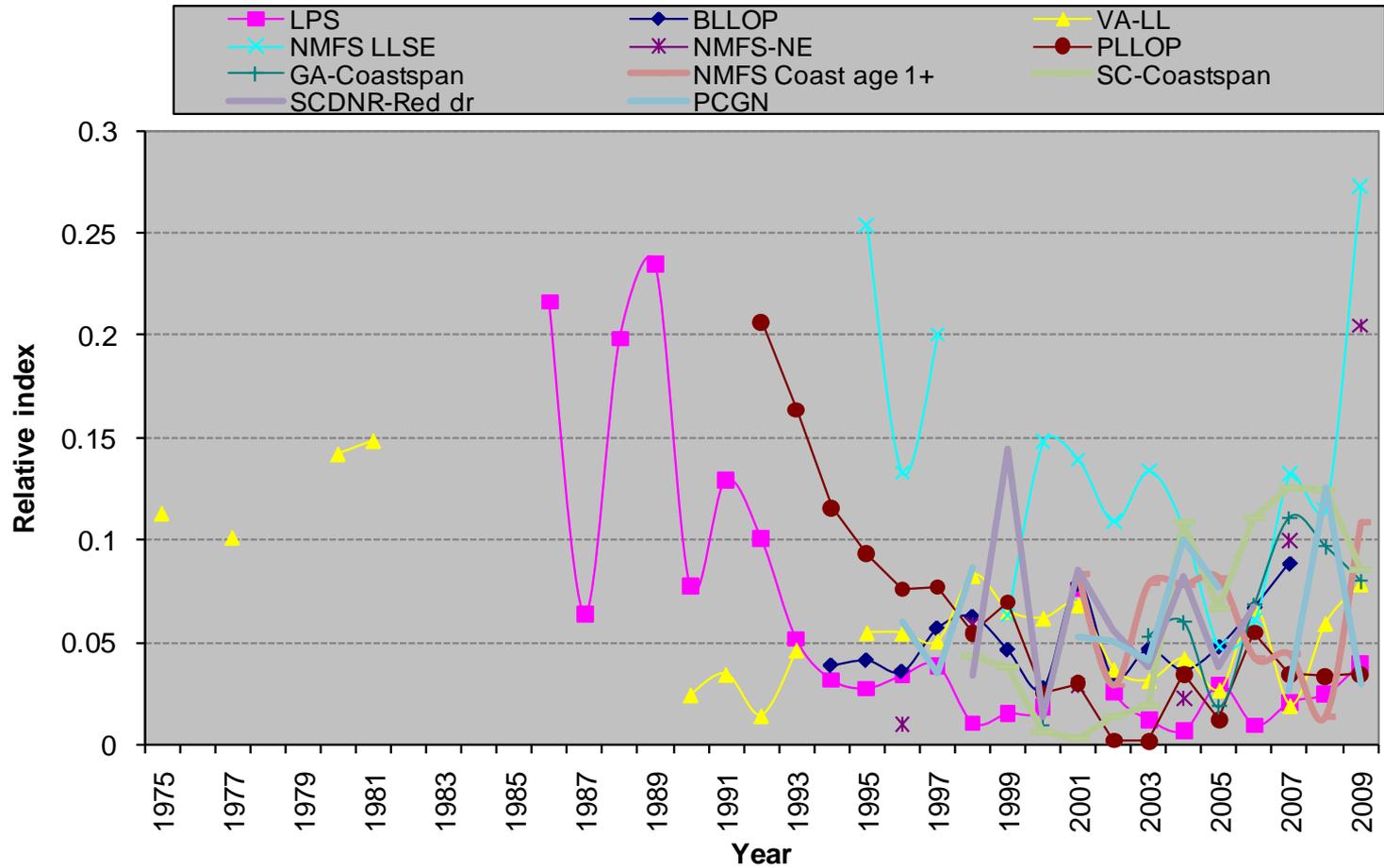
Sandbar shark

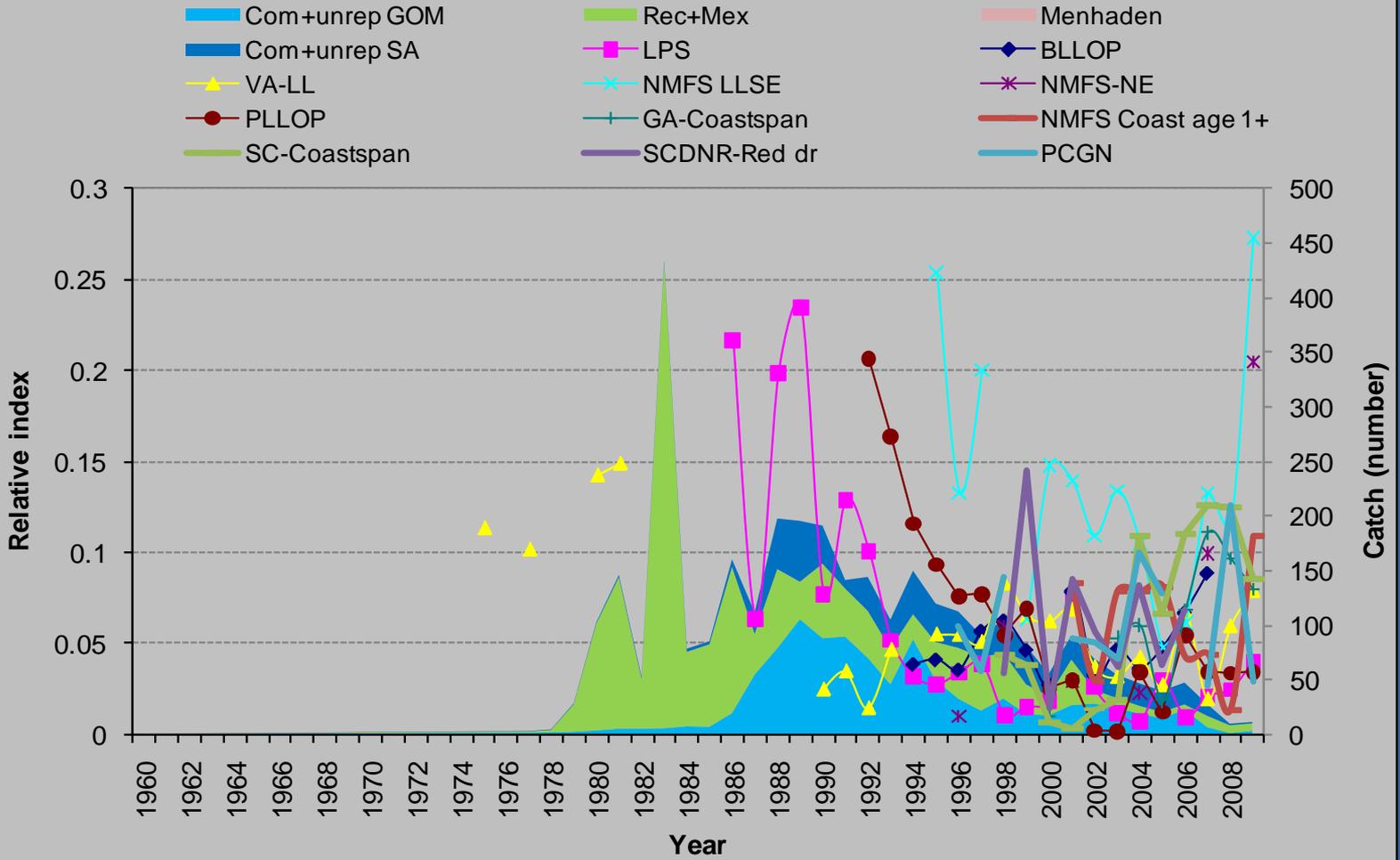


1a. Fishery Inputs

- Indices of Abundance (11):
 - BLLOP, VA-LL, LPS, PLLOP, NMFS LL NE, NMFS Coastspan Age 1+, GA Coastspan, SC Coastspan, SC Red drum historic, PCGN, NMFS LL SE

INDICES





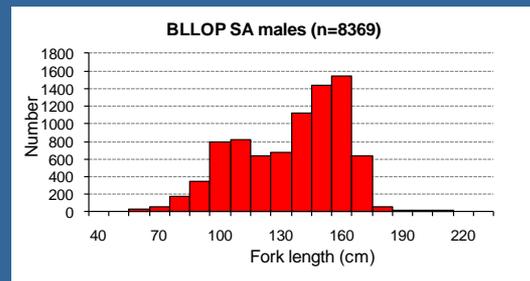
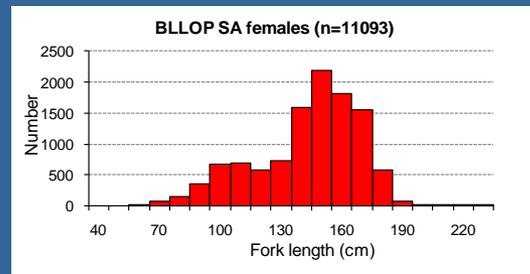
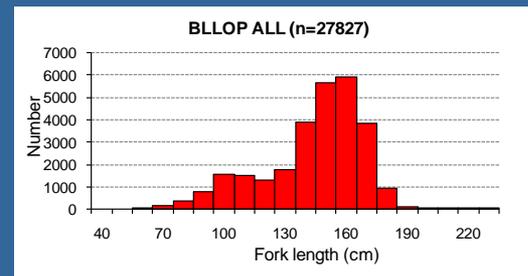
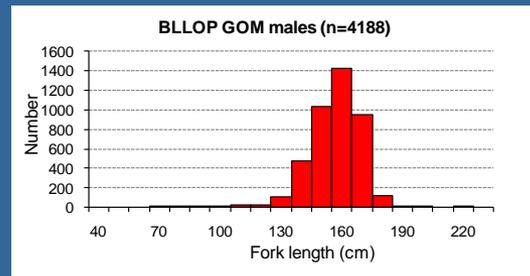
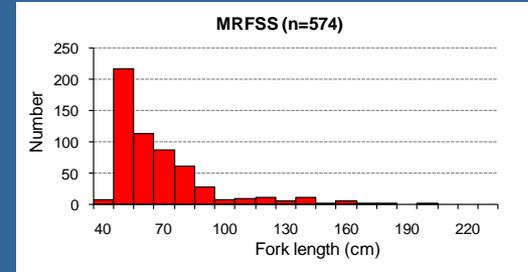
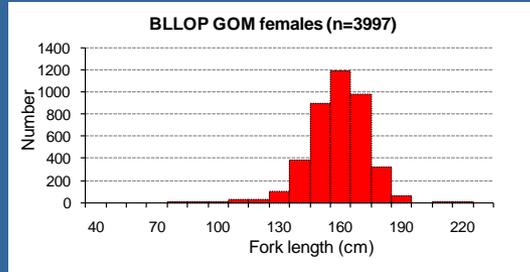
Selectivity Derivations

- Selectivity reflects both vulnerability to gear as well as availability to fishery
- Limited length-frequency data converted to age-frequency data through an age-length key
- Age-frequency data fitted statistically or by eye and considering collective knowledge of fisheries of AP participants (see "[ALK and selectivity computation_SEDAR 21_Sept162010_revised.pptx](#)" for details)

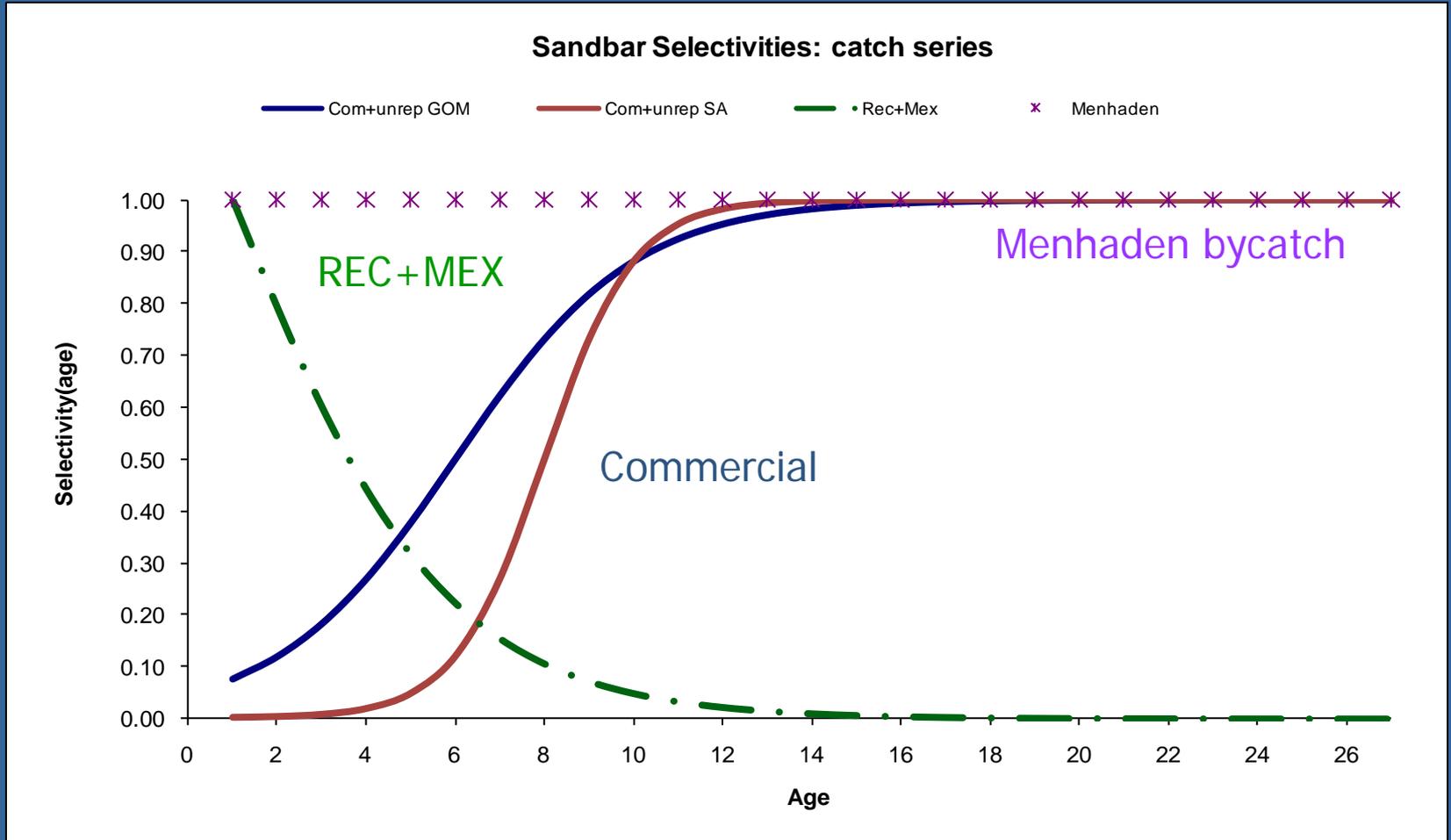
1a. Fishery Inputs

- Selectivity for catches:
 - Commercial + Unreported Commercial GOM
 - Commercial + Unreported Commercial SA
 - Recreational + Mexican
 - Menhaden discard

Length Compositions



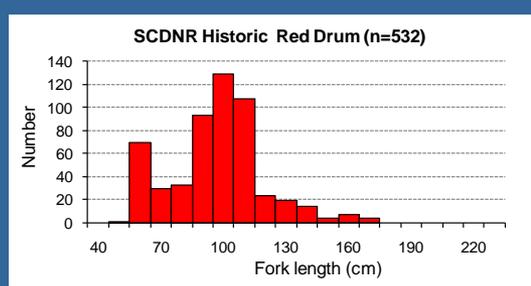
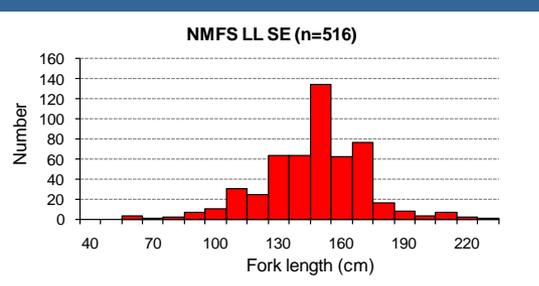
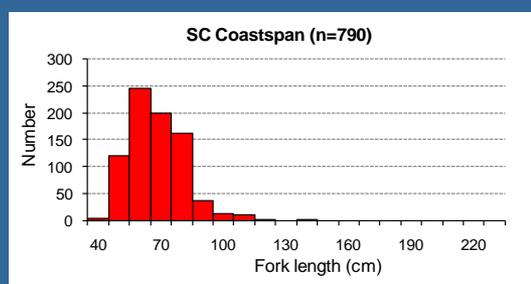
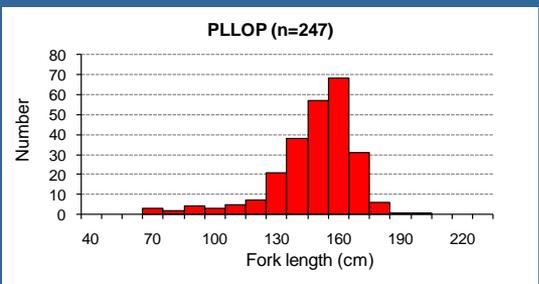
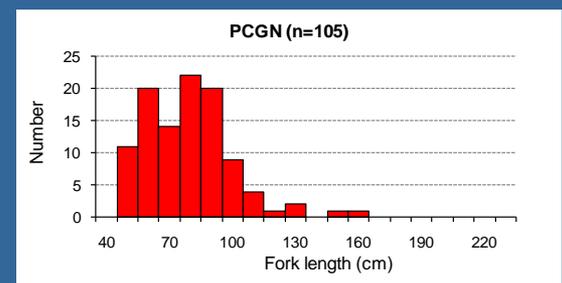
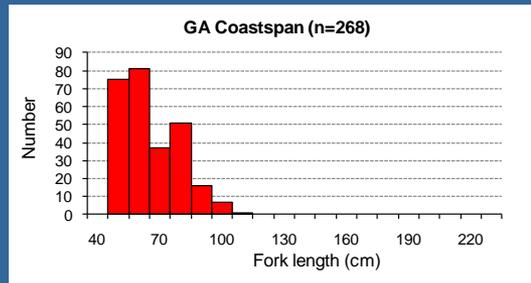
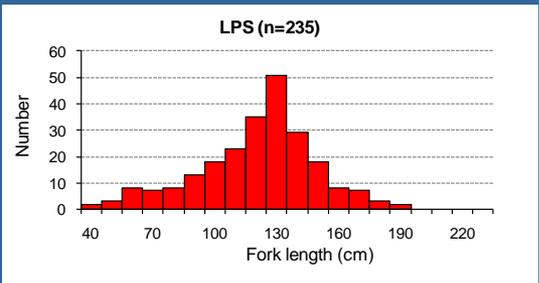
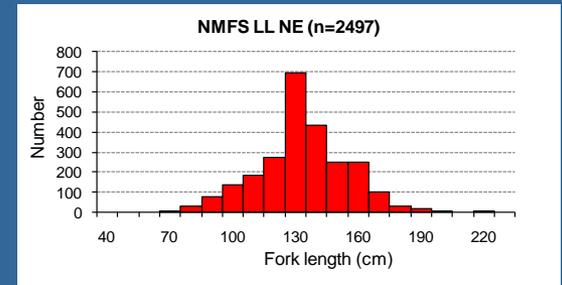
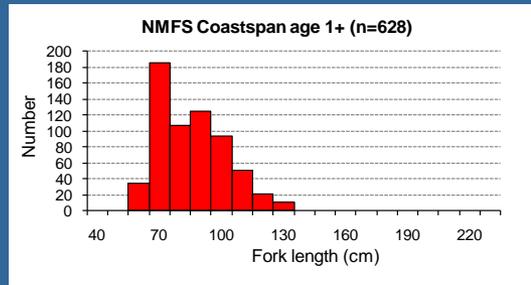
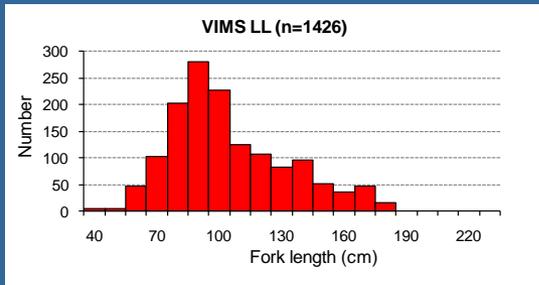
Selectivity - Catch



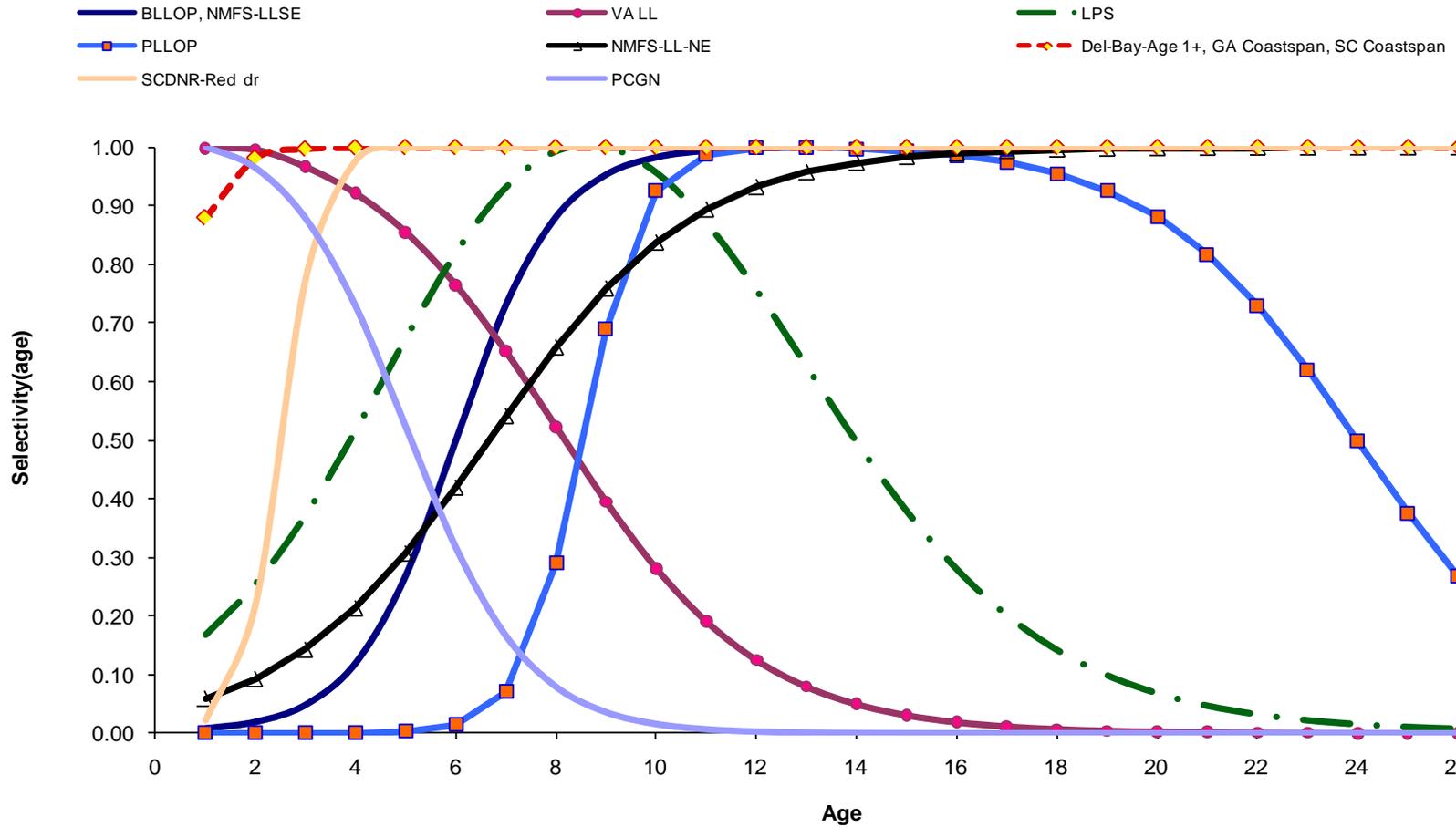
1a. Fishery Inputs

- Selectivity for Indices:
 - BLLOP, NMFS LL SE
 - VA-LL
 - LPS
 - PLLOP
 - NMFS LL NE
 - DEL Bay Age 1+, GA Coastspan, SC Coastspan
 - SC Red drum historic
 - PCGN

Length Compositions

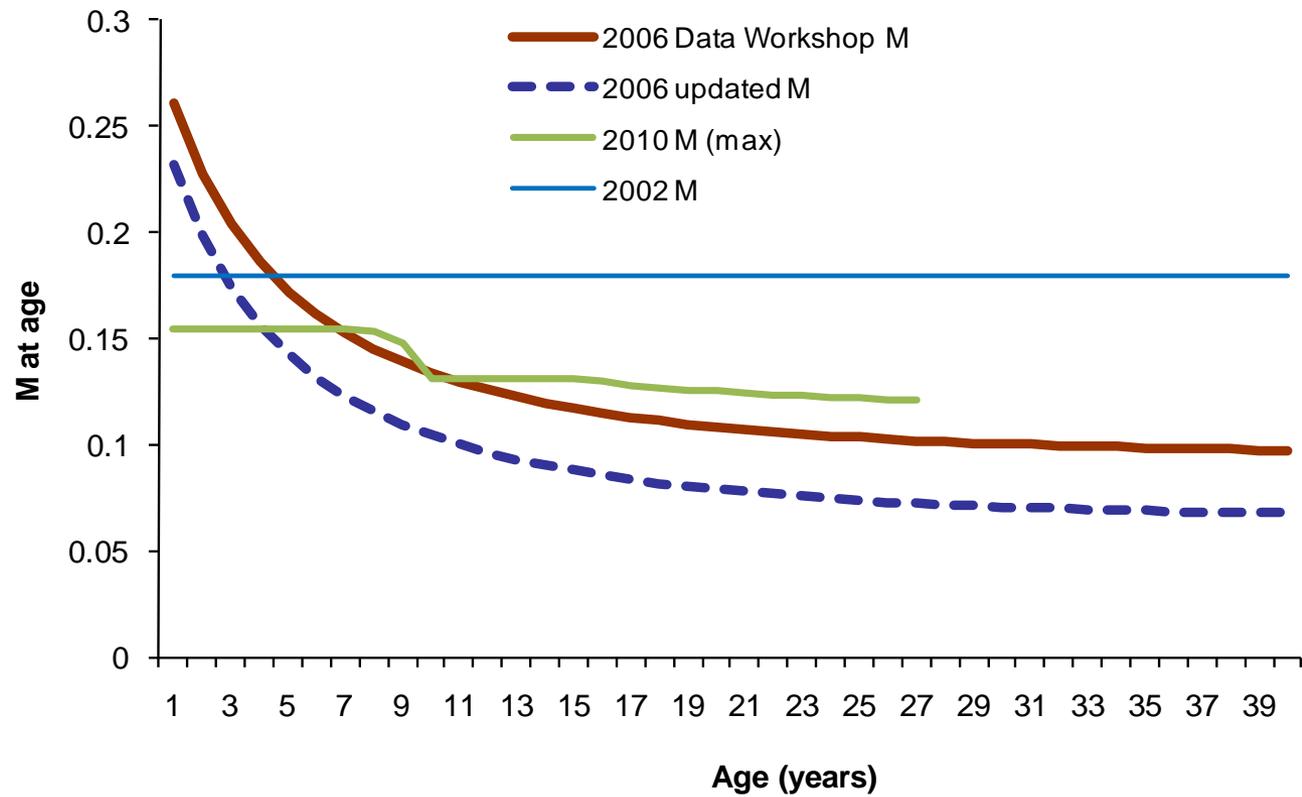


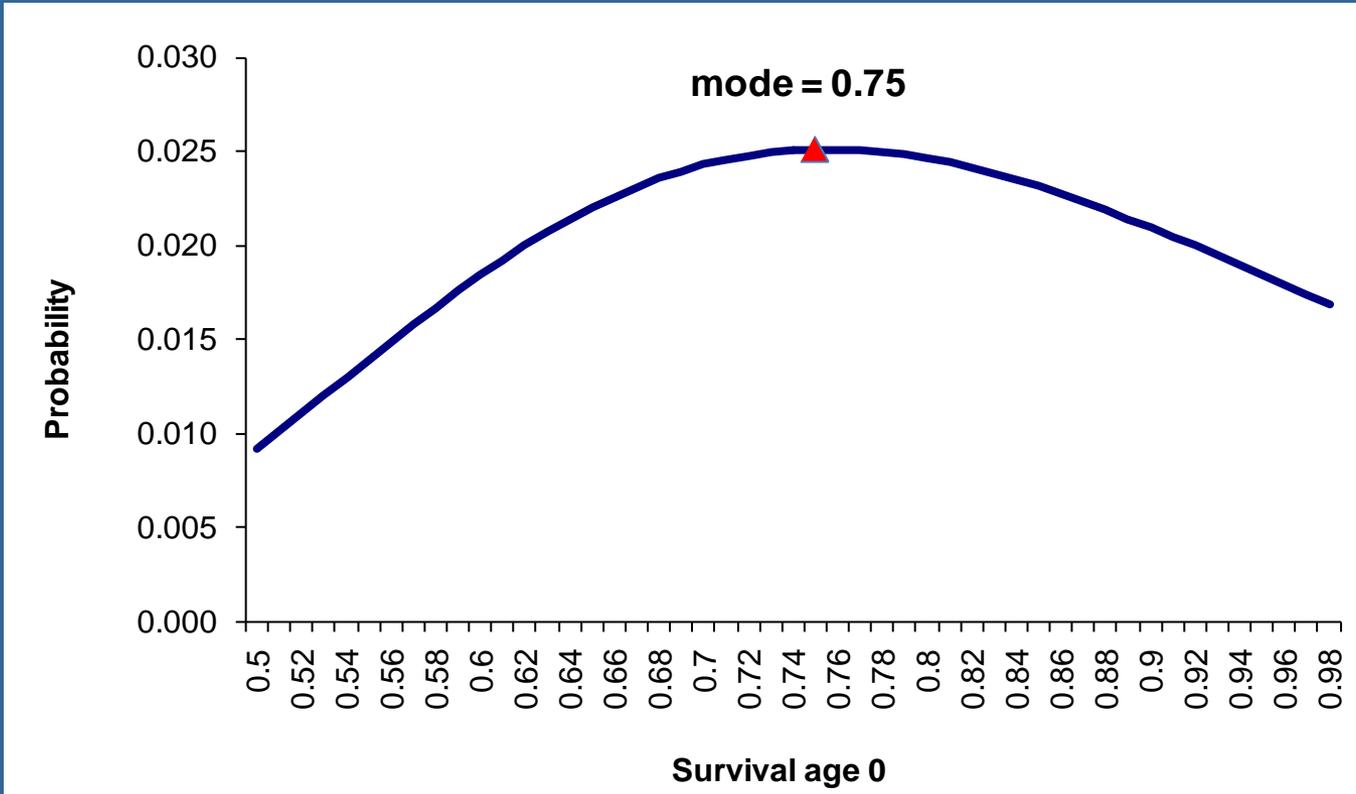
Selectivity - Indices



1b. Biological Inputs

- Pup-production: $\text{pups} = 0.2591 * \text{age} + 3.9897$
- Parturition frequency: biennial-triennial (2.5 yrs)
- Natural Mortality: $0.15 \rightarrow 0.12$
- Pup-Survival: mode 0.75
- Maturity: $\sim 50\%$ age 13.5;
 $\sim 99\%$ age 20





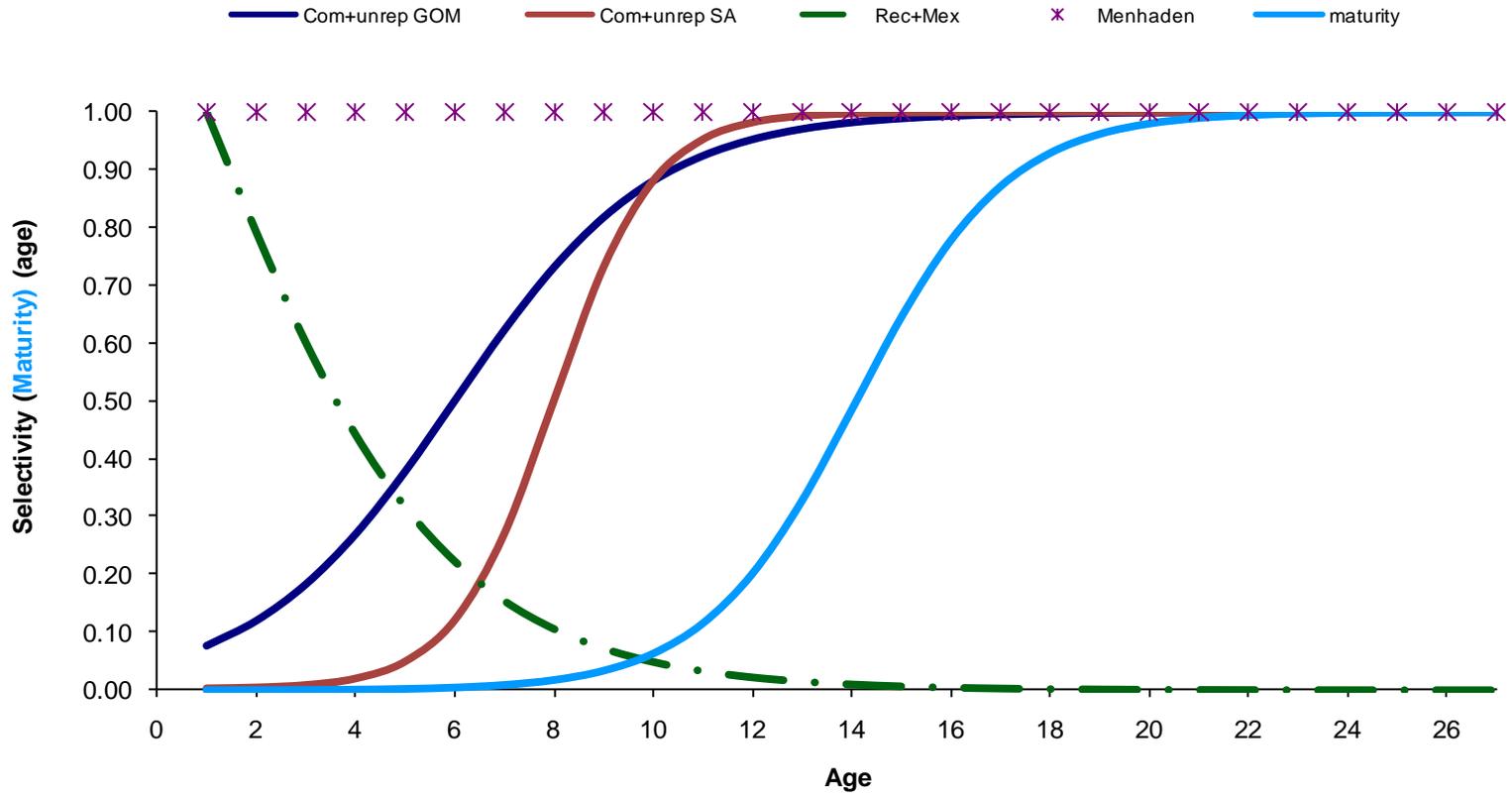
Prior for S0:

Lognormal with median 0.81, CV = 0.3

(mean = 0.85; mode = 0.75)

bounds: [0.5 , 0.98]

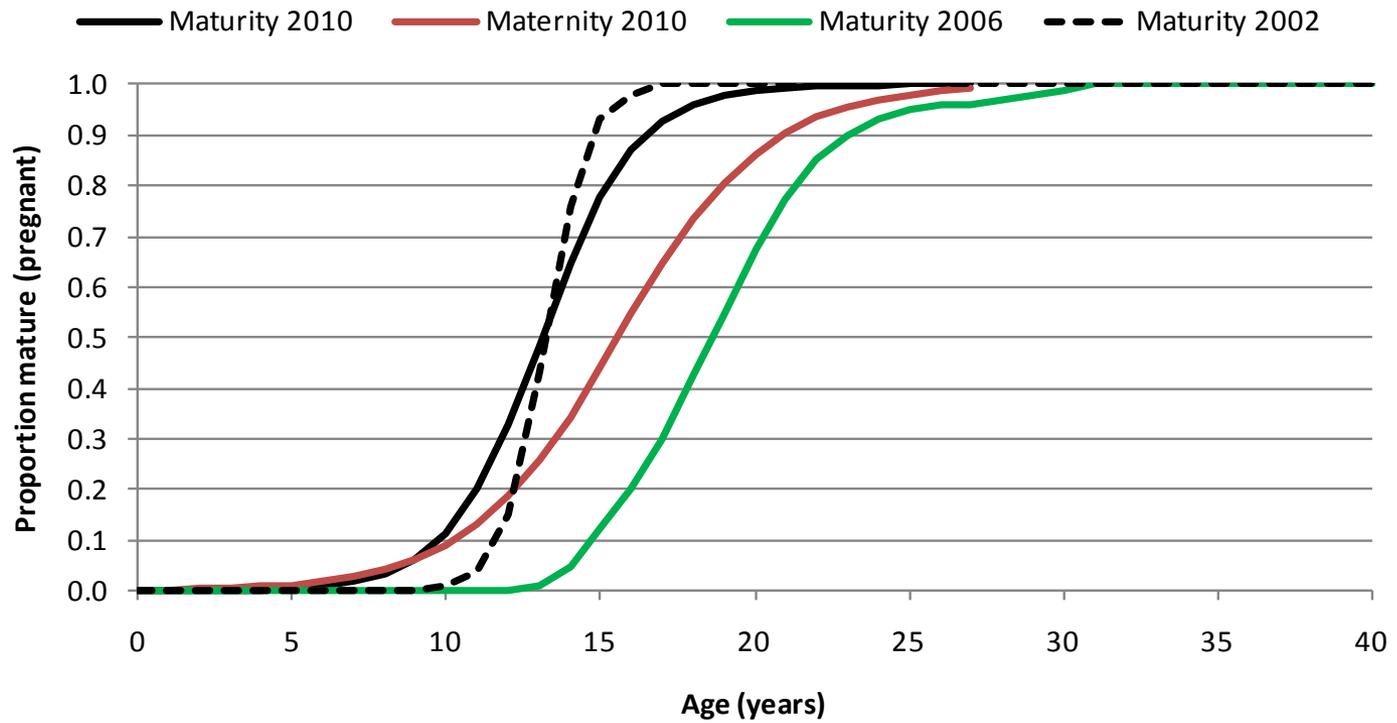
Sandbar Selectivities: catch series



Maturity Studies

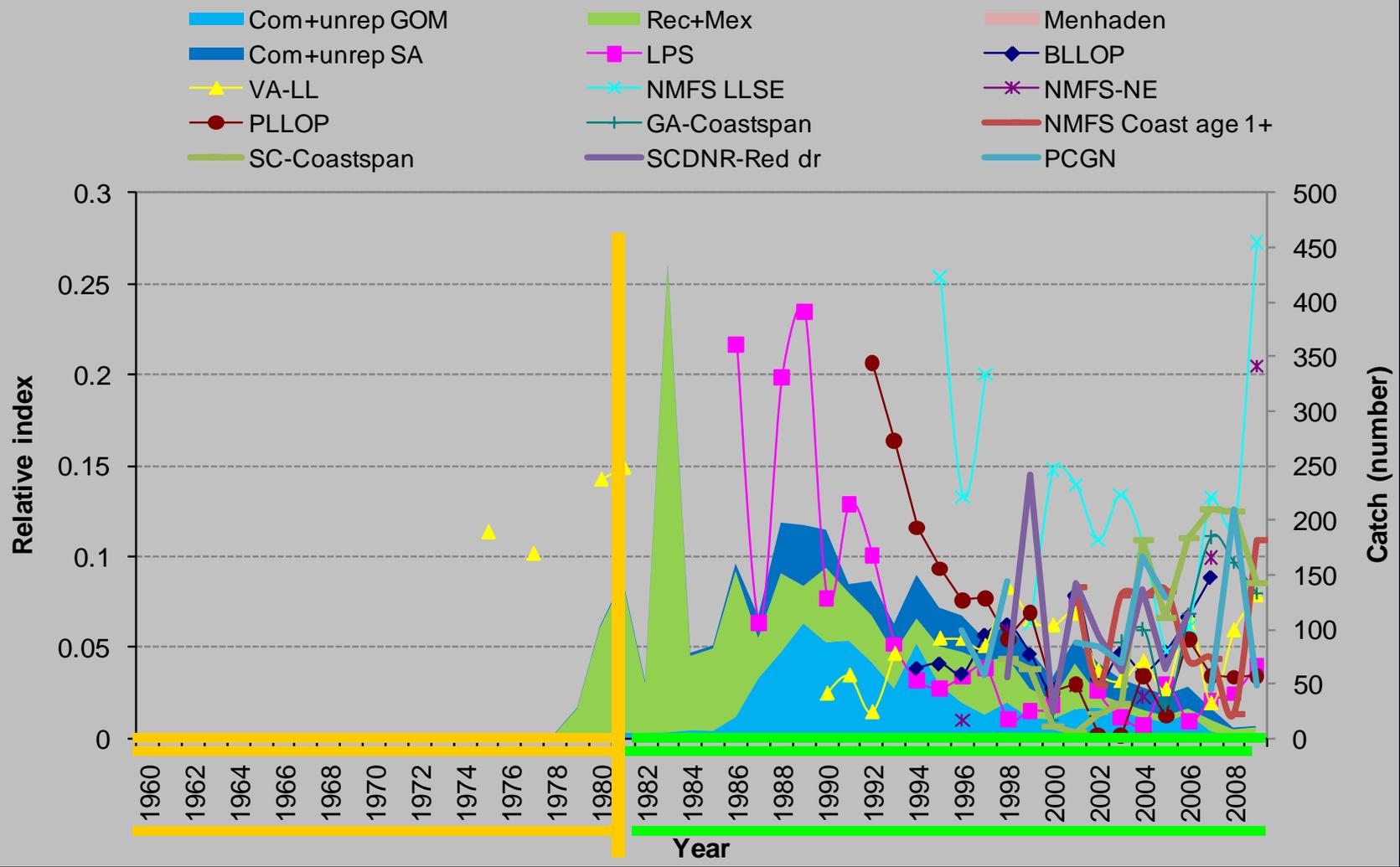
- **2002 assessment:** Age and growth study by Sminkey and Musick (1995); mentioned size at 50% and 100% maturity
- **2006 assessment:** Merson (1998) reproductive study; used Sminkey and Musick growth model to convert size to age; Merson's study was revisited prior to AW, supplemented with additional reproductive information → same conclusion
- **2010 assessment:** New age and growth and reproductive study (animals for which maturity status was assessed were also aged)

Maturity-Maternity ogives



2. Model Description

- Catch series begin in 1981; earliest index (VA LL) begins in 1975
- Catches from 1960-1980 were estimated (linear increase from 1960 to 1975, exponential from 1975 to 1981)



historic

modern

1960-1980

1981-2009

3. Base Model and Results

- Virgin conditions: 1960
- 'Estimated' historical catches
- Updated biological parameters
- Base case indices (11)
- Historic catches downweighted by $\frac{1}{2}$
- Rec 1983 catch downweighted by $\frac{1}{10}$
- Catches "fit" 5 times "better" than indices
- Equal weighting of indices

Base model Results

2010 base run

2006 base run

(data to 2009)

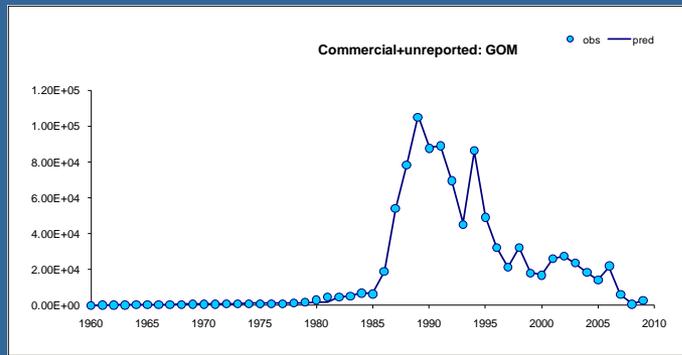
(data to 2004)

OVERFISHED

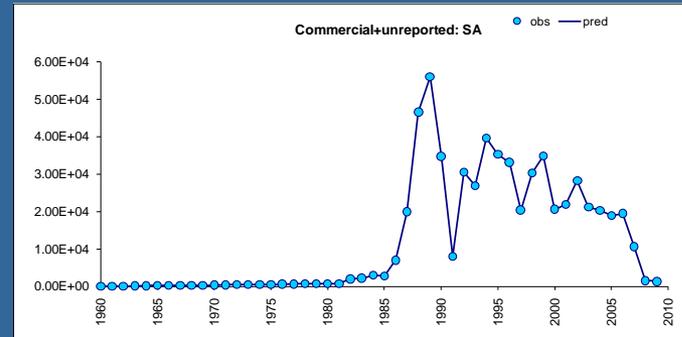
■ $SSF_{2004 \text{ or } 2009} / SSF_{MSY} =$	0.66	0.72
■ $F_{2004 \text{ or } 2009} / F_{MSY} =$	0.62	3.72
■ Steepness =	0.29	0.32
■ $SPR_{MSY} =$	0.78	0.73
■ $F_{MSY} =$	0.021	0.015

NO OVERFISHING

CATCHES

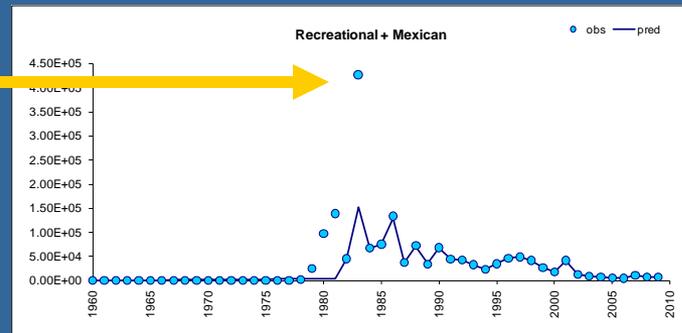


Commercial +
Unreported GOM

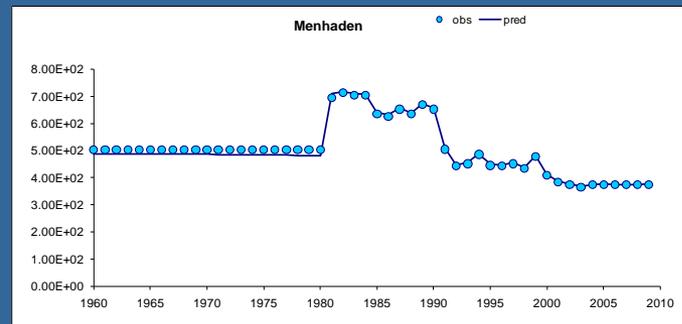


Commercial +
Unreported SA

downweighted

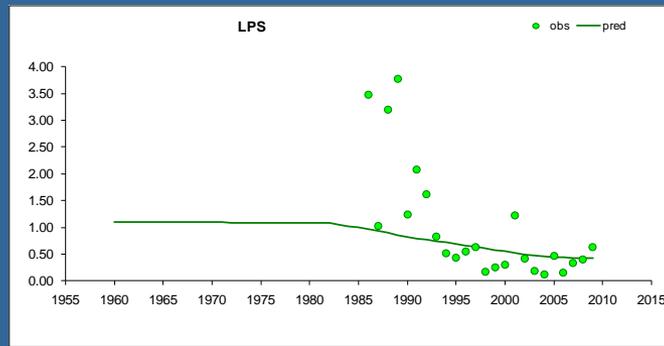


Recreational
+ Mexican

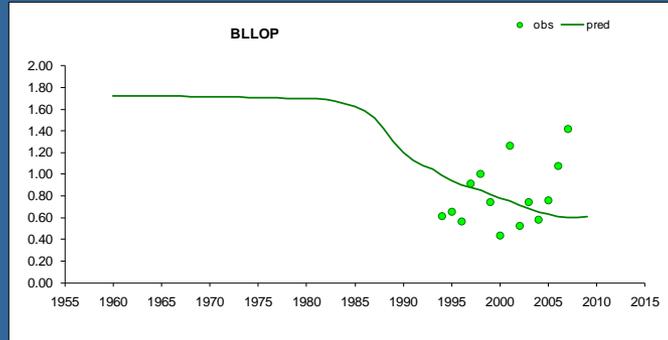


Menhaden
discards

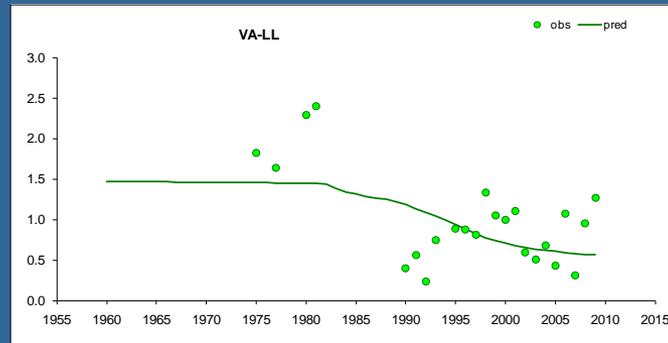
INDICES



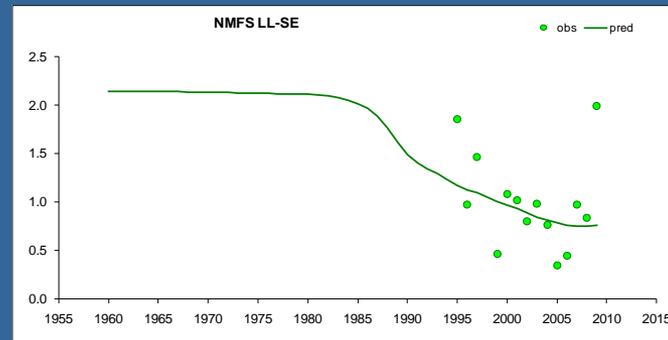
LPS



BLLOP

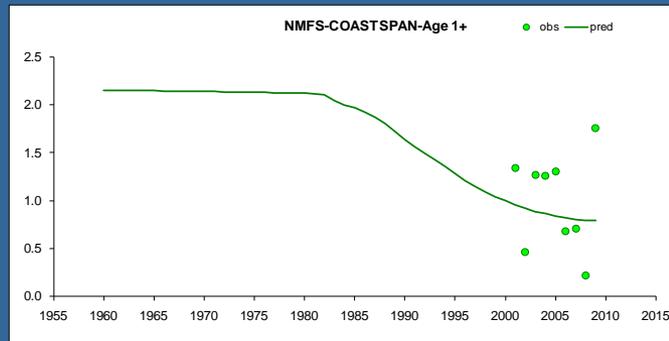


VA LL

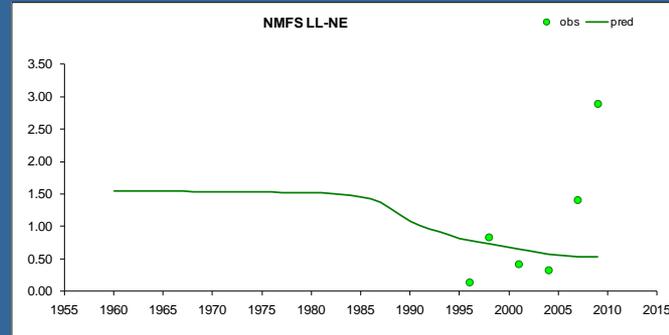


NMFS-LL-SE

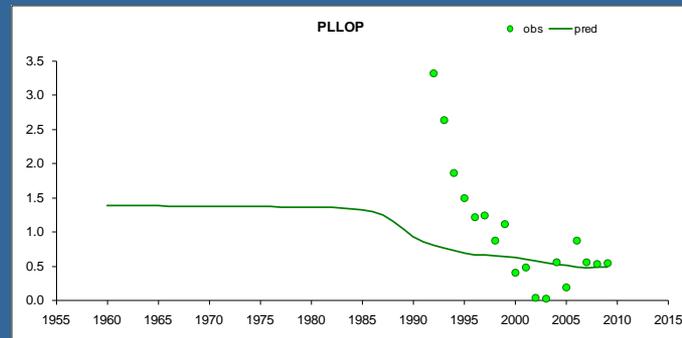
INDICES



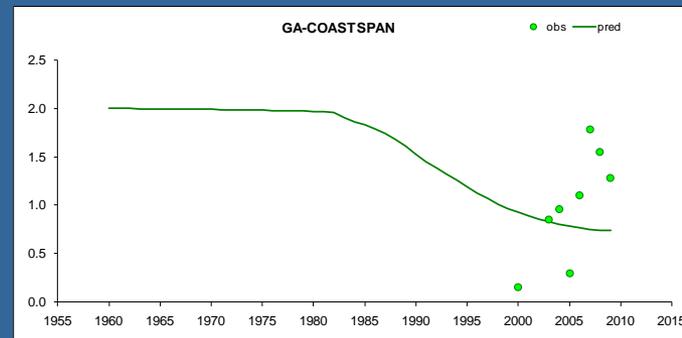
NMFS Coastspan
age1+



NMFS LL NE

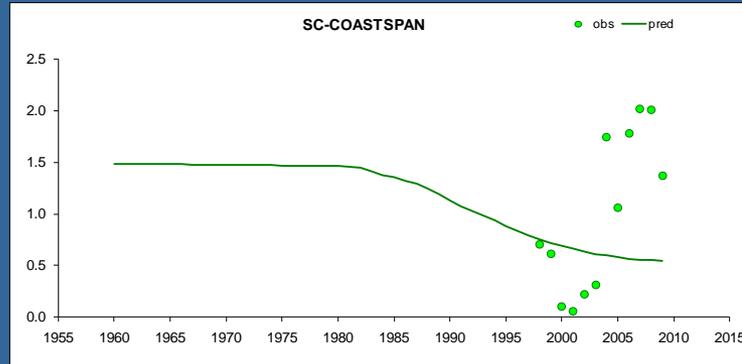


PLLOP

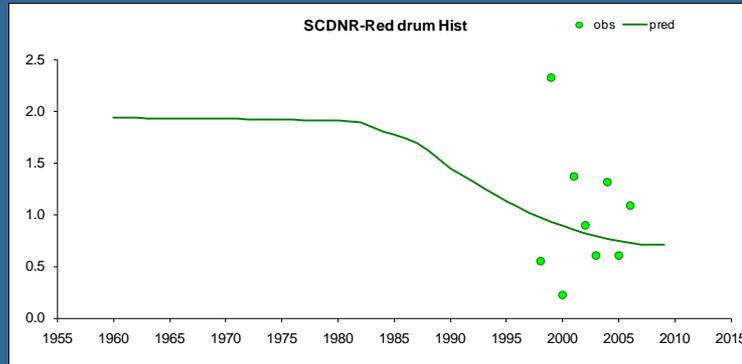


GA Coastspan

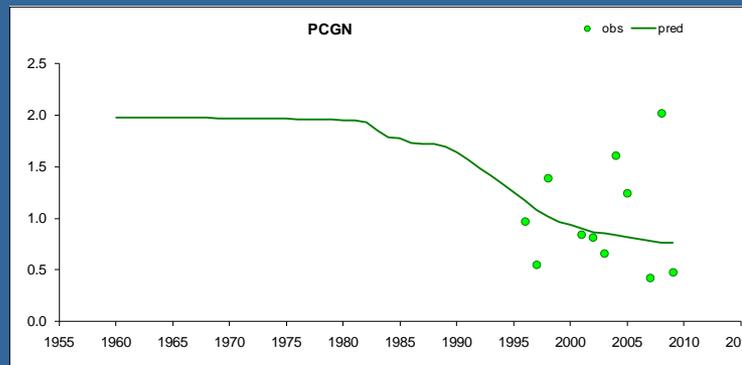
INDICES



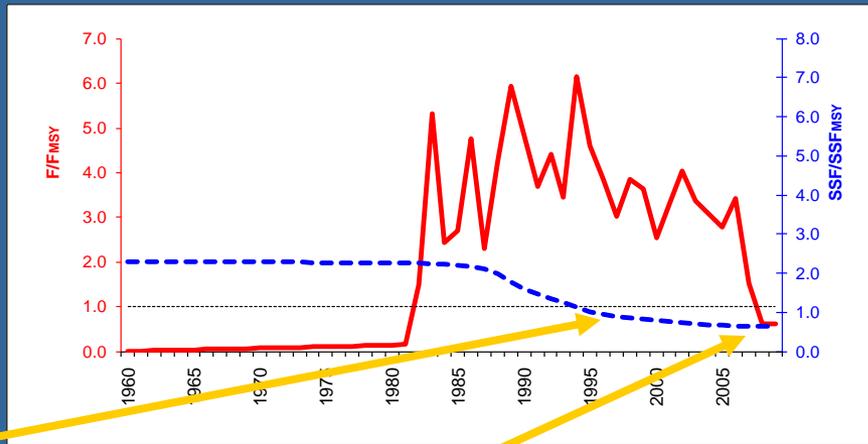
SC Coastspan



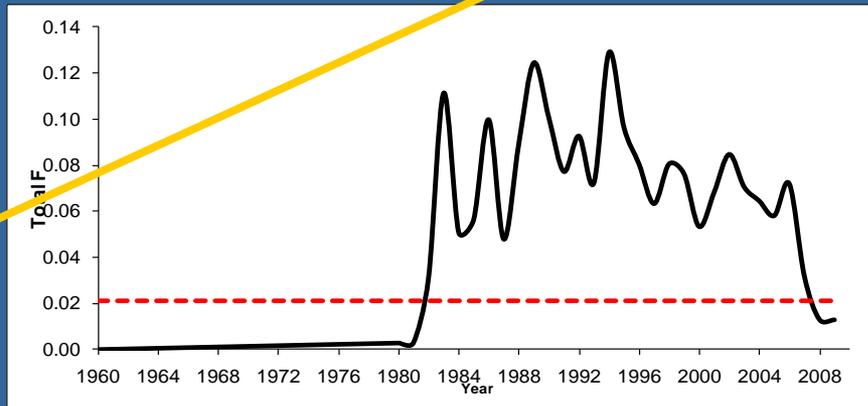
SCDNR Red drum historic



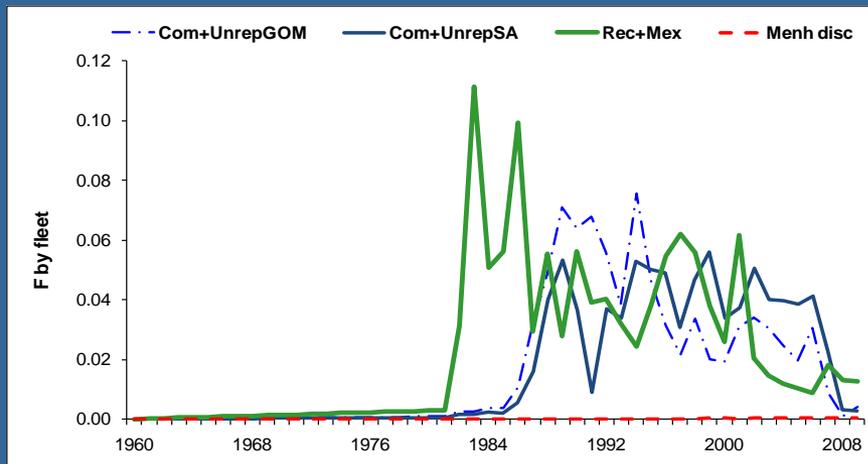
PCGN



F/F_{MSY} and B/B_{MSY}



Total F and F_{MSY}



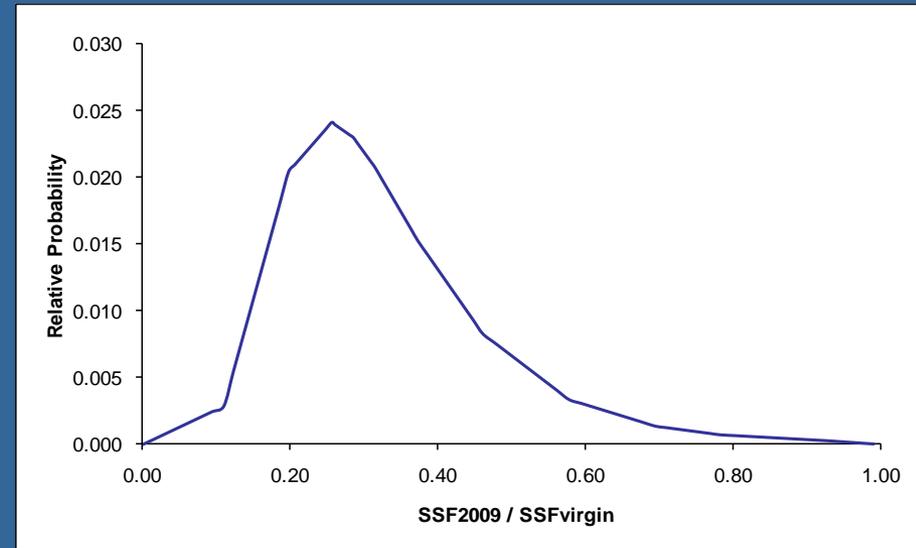
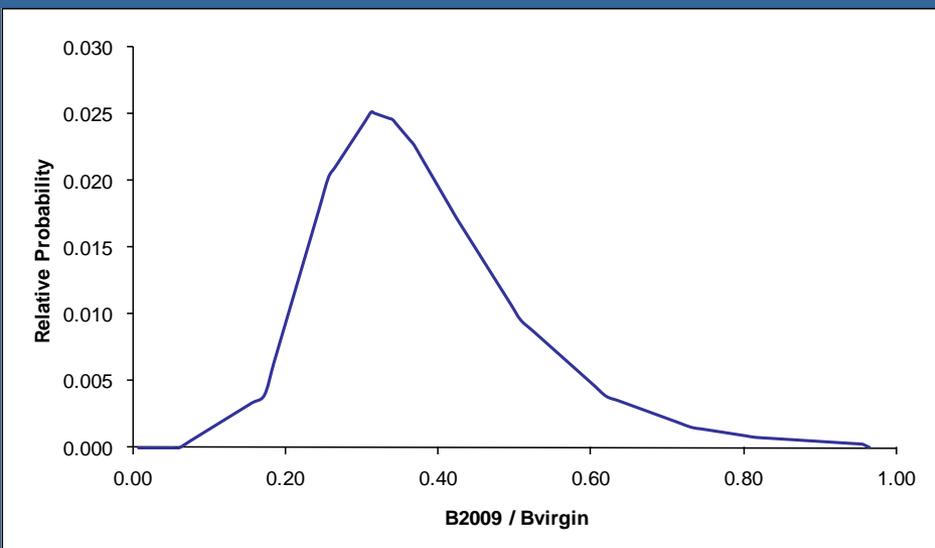
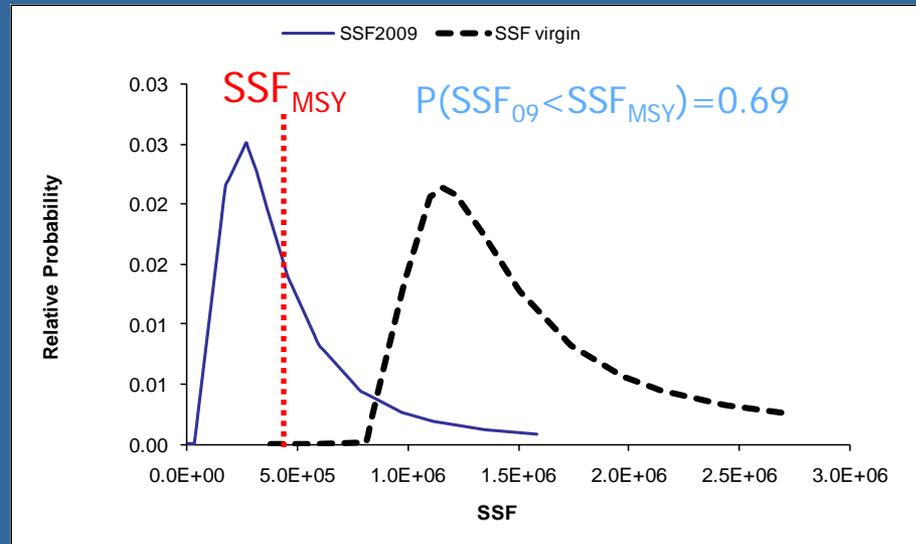
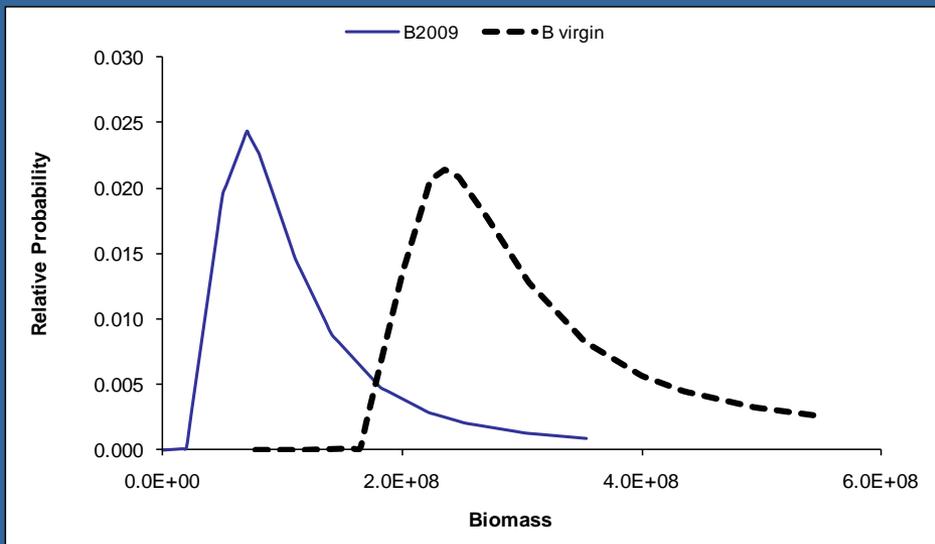
F by fleet

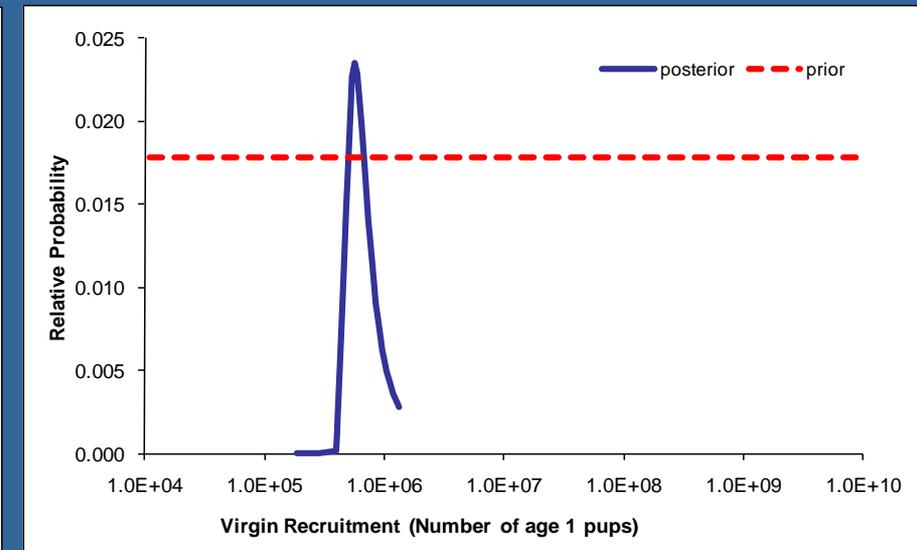
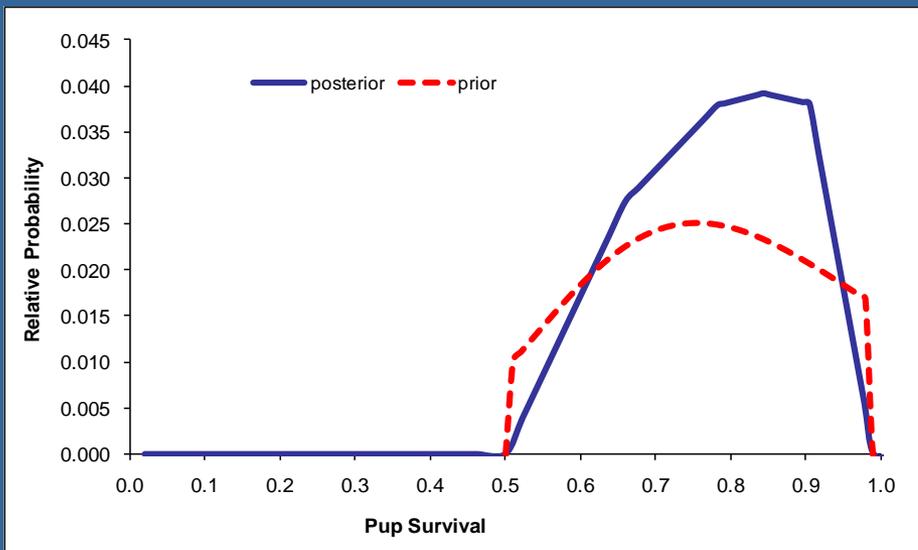
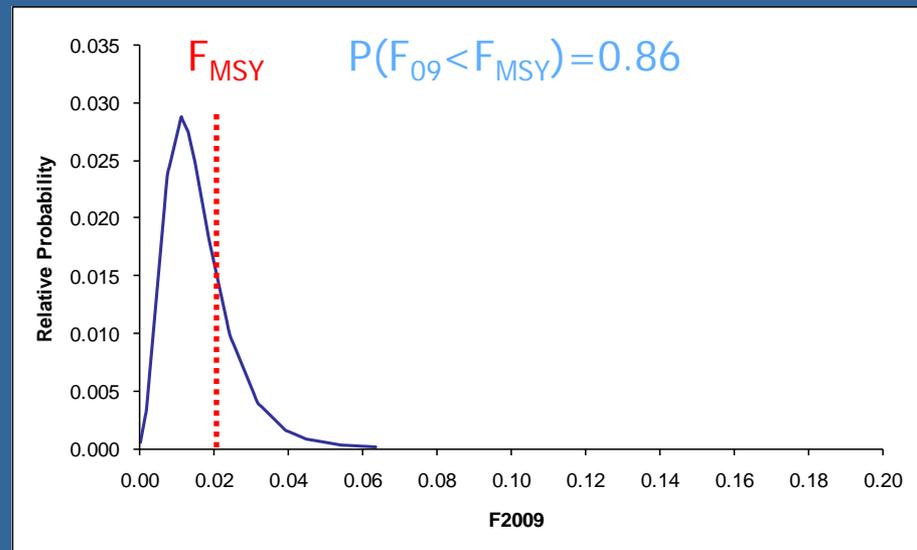
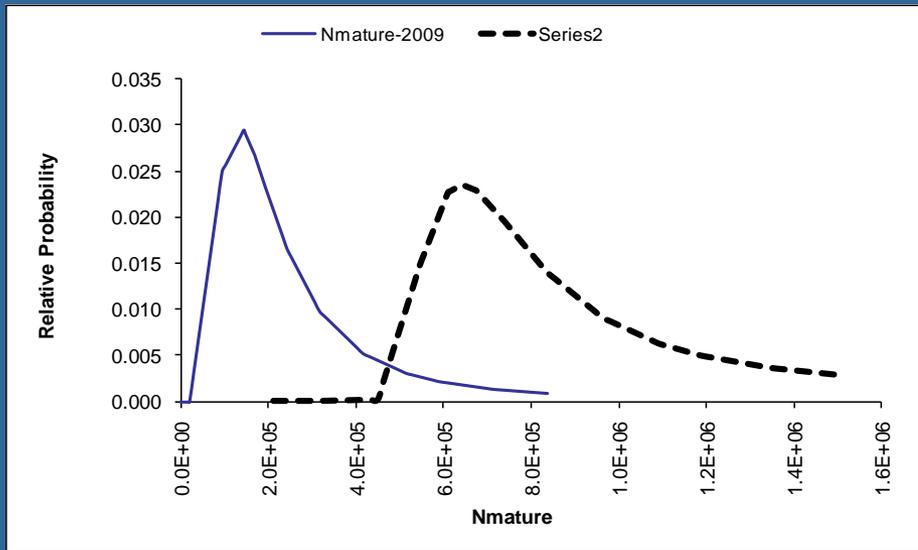
Overfished since 1996

No overfishing since 2008

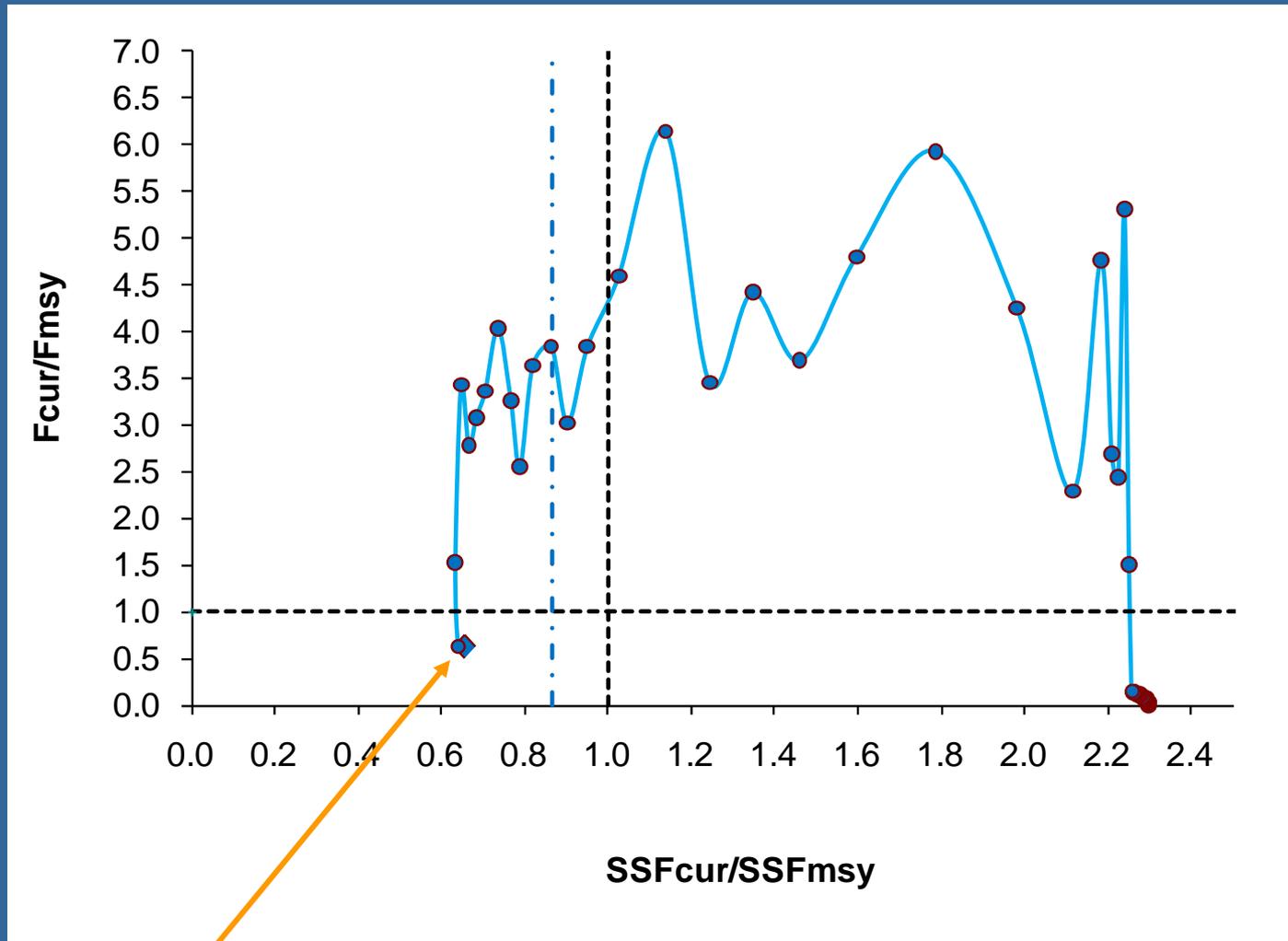
Uncertainty

- Likelihood profiling option in ADMB to estimate posterior distributions for parameters





Stock status trajectory for base run



2009 status
(69%, 86%)

4. Sensitivity Analyses

- S1: inverse CV weighting of indices
- S2: all CPUE series
- S3: combined commercial catches
- S4: combined commercial catches and inverse CV
- S5: 2-yr reproductive cycle
- S6: 3-yr reproductive cycle
- S7: U-shaped M
- S8: Fishery-independent indices only

Sensitivity Analyses (continued)

- S9: Rank-based weighting of indices
- S10: Hierarchical index
- S11: Hierarchical index (no weighting)
- S12: Low catch
- S13: High catch
- S14: Low M (-10%)
- S15: High M (+10%)
- S16: Alternative historical catches (linear increase from 1960 to 1981)

5. Summary of all Results

	Base		S1 (inverse CV)		S2 (all indices)		S3 (combined catch)		S4 (comb catch inv CV)		S5 (2-yr cycle)		S6 (3-yr cycle)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	718.01		652.84		767.34		617.71		538.54		717.81		718.71	
Objective function	117.95		85.37		158.18		133.56		93.98		117.85		118.30	
SSF ₂₀₀₉ /SSF _{MSY}	0.66	0.83	0.56	0.70	0.81	0.52	0.78	0.73	0.58	0.73	0.64	0.71	0.66	1.09
F ₂₀₀₉ /F _{MSY}	0.62	0.57	0.62	0.44	0.46	0.52	0.53	0.30	0.61	0.30	0.46	0.55	0.93	0.61
N ₂₀₀₉ /N _{MSY}	0.74	---	0.38	---	0.49	---	0.48	---	0.38	---	0.43	---	0.43	---
MSY	160643	---	264367	---	313002	---	299543	---	252875	---	264927	---	313581	---
SPR _{MSY}	0.78	0.06	0.74	0.09	0.77	0.11	0.79	0.01	0.74	0.01	0.69	0.09	0.86	0.04
F _{MSY}	0.021	---	0.025	---	0.022	---	0.020	---	0.026	---	0.030	---	0.030	---
SSF _{MSY}	477590	---	430320	---	507410	---	509800	---	402450	---	503420	---	503420	---
N _{MSY}	1928165	---	3120188	---	3741763	---	3608844	---	2971324	---	3063451	---	3639906	---
F ₂₀₀₉	0.01	0.57	0.02	0.44	0.01	---	0.01	0.30	0.02	0.30	0.01	0.55	0.01	0.61
SSF ₂₀₀₉	312890	0.60	240950	0.40	410450	0.38	397980	0.37	234890	0.37	319760	0.59	313510	0.63
N ₂₀₀₉	1539102	---	1277408	---	1966818	---	1857216	---	1219683	---	1408804	---	1688767	---
SSF ₂₀₀₉ /SSF ₀	0.28	0.41	0.24	0.27	0.34	0.33	0.35	0.25	0.24	0.25	0.25	0.42	0.32	0.41
B ₂₀₀₉ /B ₀	0.34	0.33	0.30	0.18	0.40	0.27	0.40	0.18	0.30	0.18	0.33	0.33	0.35	0.34
R ₀	563490	0.20	516900	0.14	612910	0.08	587230	0.16	494350	0.16	516810	0.18	612140	0.23
Pup-survival	0.84	0.29	0.94	0.30	0.86	0.00	0.82	0.29	0.94	0.29	0.84	0.29	0.84	0.29
alpha	1.64	---	1.84	---	1.67	---	1.59	---	1.82	---	2.05	---	1.37	---
steepness	0.29	---	0.31	---	0.29	---	0.28	---	0.31	---	0.34	---	0.25	---

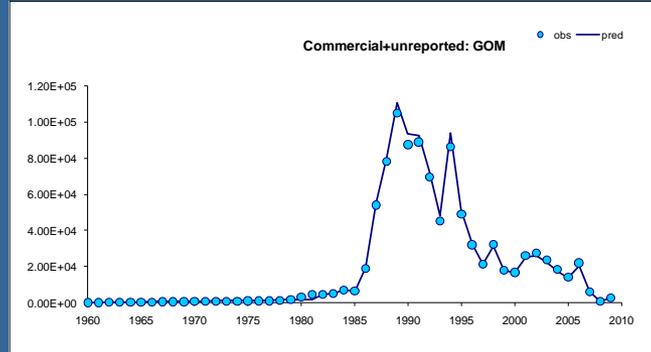
5. Summary of all Results (continued)

	S7 (U-shaped M)		S8 (F-I indices)		S9 (ranked indices)		S10 (hierarchical ind)		S11 (hier ind, no wt)		S12 (low catch)		S13 (high catch)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	717.40		721.25		791.27		753.73		781.79		712.71		716.79	
Objective function	117.64		93.60		154.58		51.94		65.97		115.30		117.34	
SSF ₂₀₀₉ /SSF _{MSY}	0.57	0.59	1.17	0.83	0.66	0.85	0.61	0.82	0.41	1.07	0.66	0.79	0.77	0.81
F ₂₀₀₉ /F _{MSY}	0.41	0.51	0.26	0.95	0.63	1.02	0.67	0.57	1.14	0.83	0.70	0.57	0.21	0.58
N ₂₀₀₉ /N _{MSY}	0.43	---	0.67	---	0.42	---	0.39	---	0.27	---	0.43	---	0.46	---
MSY	225930	---	427070	---	292289	---	282174	---	252619	---	145726	---	1350123	---
SPR _{MSY}	0.62	0.11	0.78	0.06	0.79	0.05	0.78	0.07	0.79	0.06	0.78	0.07	0.78	0.06
F _{MSY}	0.044	---	0.021	---	0.020	---	0.021	---	0.020	---	0.014	---	0.023	---
SSF _{MSY}	543750	---	721400	---	491570	---	471350	---	418530	---	249020	---	2233800	---
N _{MSY}	2501535	---	5128279	---	3522572	---	3386675	---	3046233	---	1770890	---	16150499	---
F ₂₀₀₉	0.02	0.51	0.01	0.95	0.01	1.02	0.01	0.57	0.02	0.83	0.01	0.57	0.00	0.58
SSF ₂₀₀₉	312140	0.56	841940	1.04	326150	1.07	288810	0.59	172330	0.89	163310	0.62	1722400	0.59
N ₂₀₀₉	1163572	---	3720384	---	1583756	---	1436508	---	900438	---	823421	---	7932433	---
SSF ₂₀₀₉ /SSF ₀	0.22	0.43	0.52	0.50	0.29	0.48	0.27	0.41	0.18	0.71	0.29	0.41	0.33	0.37
B ₂₀₀₉ /B ₀	0.30	0.33	0.56	0.41	0.35	0.42	0.32	0.33	0.23	0.59	0.36	0.32	0.38	0.31
R ₀	439030	0.15	836730	0.55	572880	0.59	552790	0.19	495180	0.19	285570	0.21	2644800	0.22
Pup-survival	0.85	0.29	0.85	0.29	0.83	0.29	0.85	0.29	0.81	0.29	0.86	0.29	0.84	0.29
alpha	2.69	---	1.65	---	1.61	---	1.65	---	1.59	---	1.68	---	1.63	---
steepness	0.40	---	0.29	---	0.29	---	0.29	---	0.28	---	0.30	---	0.29	---

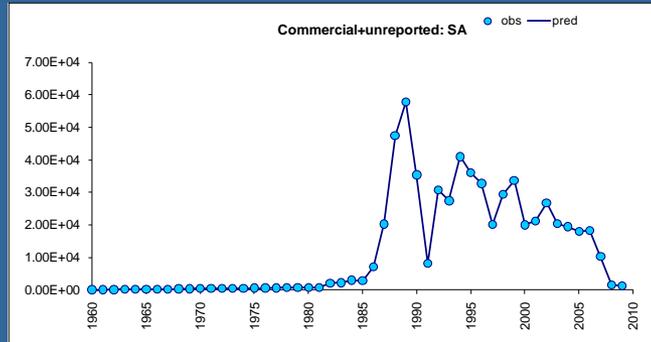
5. Summary of all Results (continued)

	S14 (low M)		S15 (high M)		S16 (alt hist catch)	
	Est	CV	Est	CV	Est	CV
AICc	717.87		718.21		134.36	
Objective function	117.88		118.05		-173.87	
SSF ₂₀₀₉ /SSF _{MSY}	0.59	0.65	0.75	1.65	0.83	1.25
F ₂₀₀₉ /F _{MSY}	0.48	0.54	1.15	0.59	0.75	0.36
N ₂₀₀₉ /N _{MSY}	0.77	---	0.74	---	0.88	---
MSY	136654	---	188038	---	227970	---
SPR _{MSY}	0.68	0.09	0.90	0.03	0.89	0.01
F _{MSY}	0.033	---	0.009	---	0.010	---
SSF _{MSY}	479160	---	481340	---	779320	---
N _{MSY}	1569644	---	2366861	---	2862847	---
F ₂₀₀₉	0.02	0.54	0.01	0.59	0.01	0.36
SSF ₂₀₀₉	282080	0.59	361100	0.59	644450	0.44
N ₂₀₀₉	1309279	---	1889311	---	2714925	---
SSF ₂₀₀₉ /SSF ₀	0.24	0.43	0.33	0.37	0.39	0.24
B ₂₀₀₉ /B ₀	0.32	0.34	0.36	0.32	0.42	0.19
R ₀	436380	0.17	744630	0.23	849350	0.20
Pup-survival	0.84	0.29	0.85	0.28	0.65	0.27
alpha	2.23	---	1.23	---	1.26	---
steepness	0.36	---	0.23	---	0.24	---

CATCHES (S1)

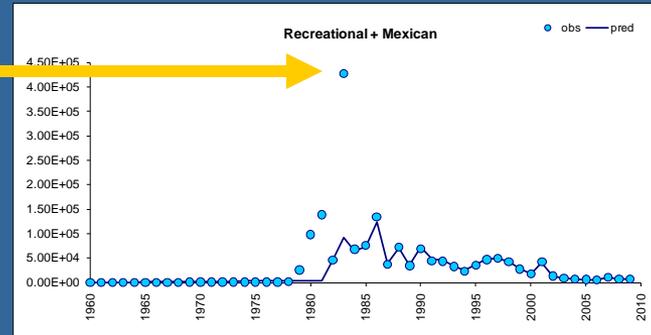


Commercial +
Unreported GOM

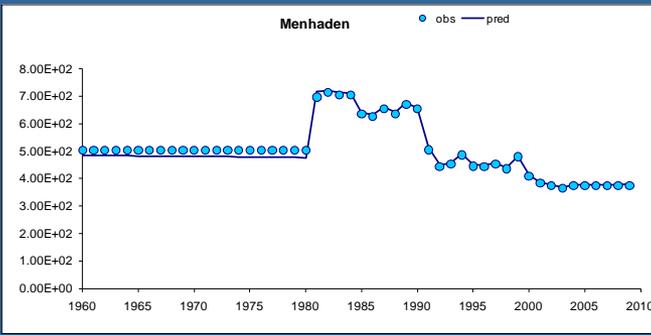


Commercial +
Unreported SA

downweighted

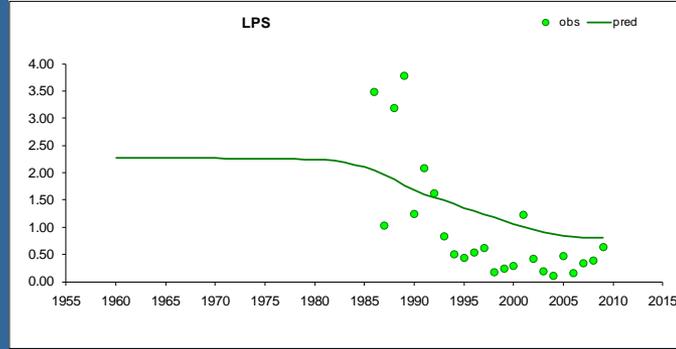


Recreational
+ Mexican

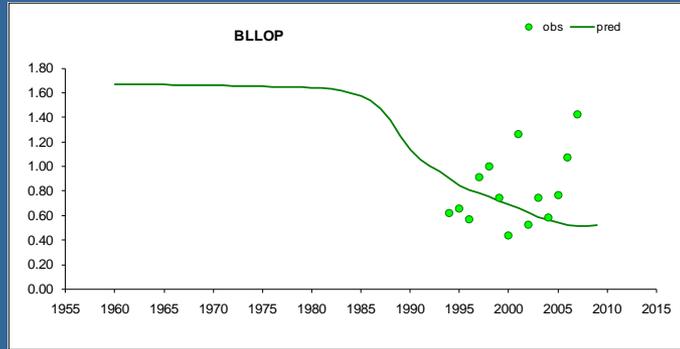


Menhaden
discards

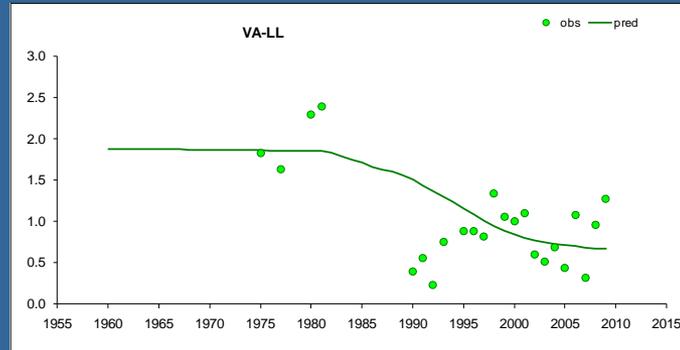
INDICES (S1)



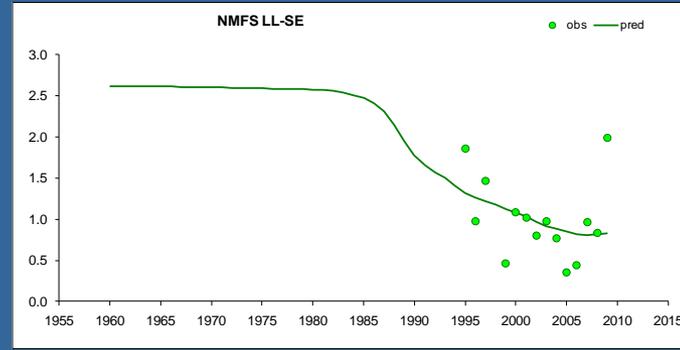
LPS



BLLOP

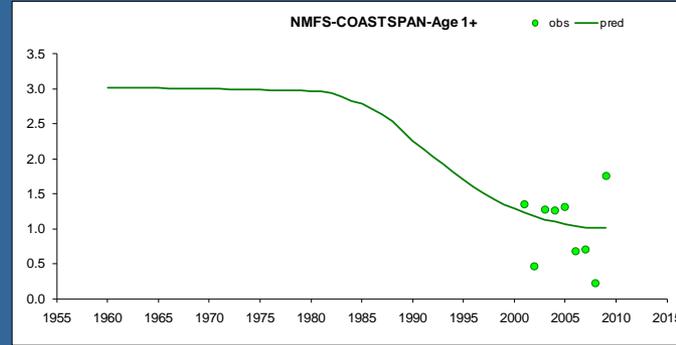


VA LL

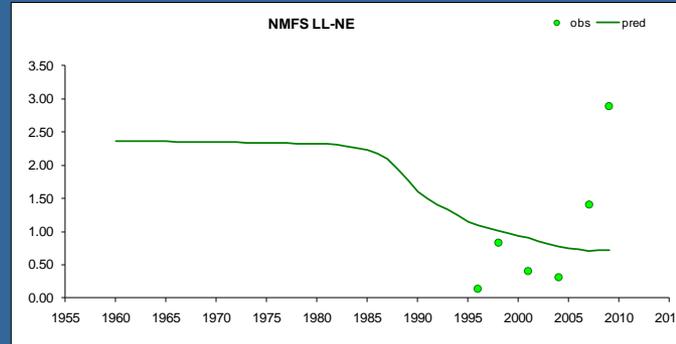


NMFS-LL-SE

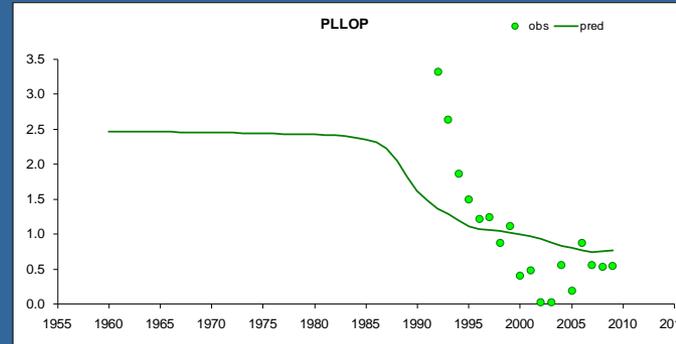
INDICES (S1)



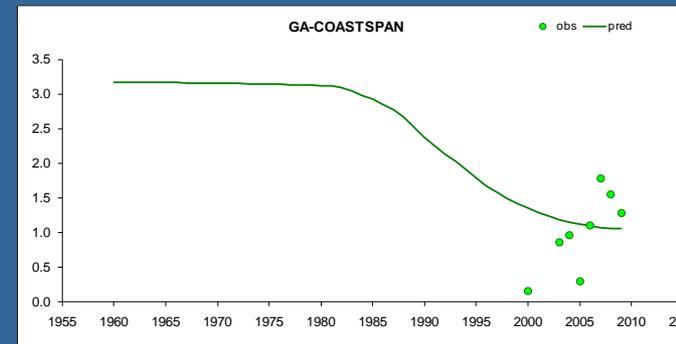
NMFS Coastspan
age1+



NMFS LL NE



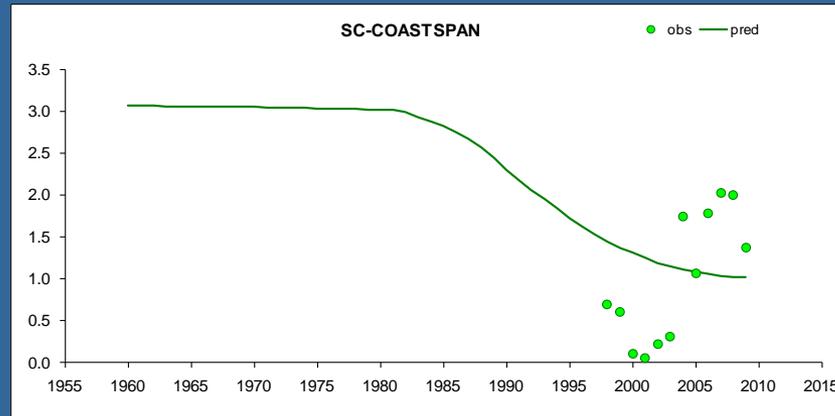
PLLOP



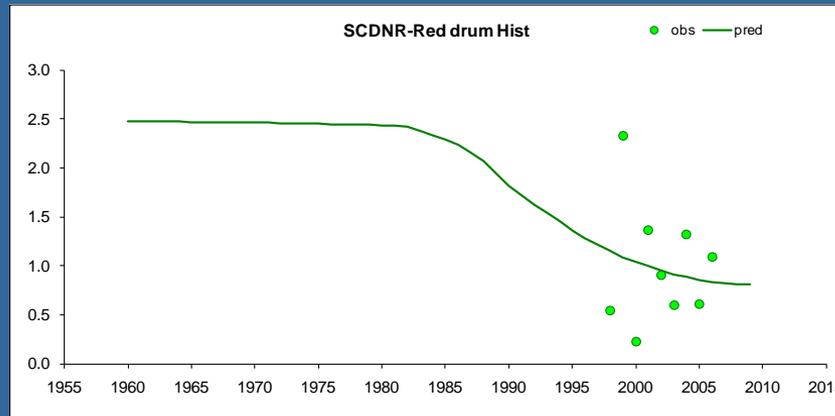
GA Coastspan

INDICES

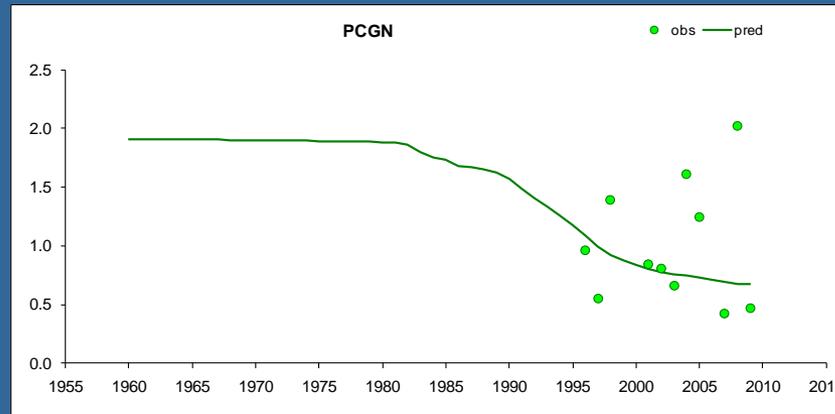
(S1)



GA Coastspan

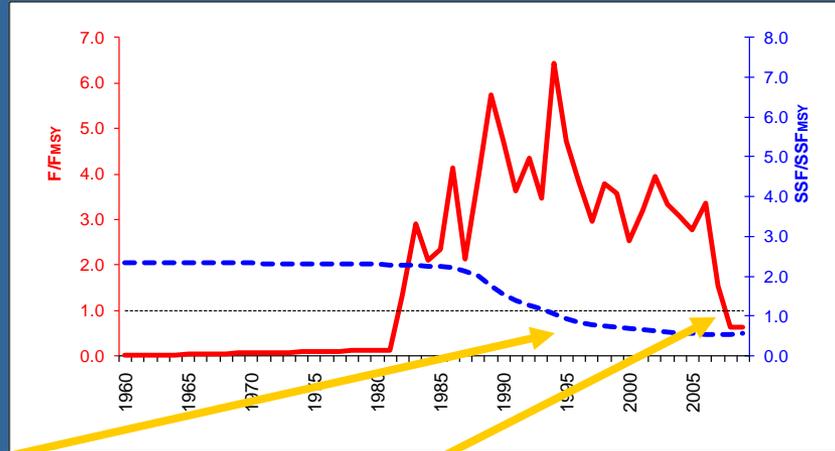


SCDNR Red drum historic

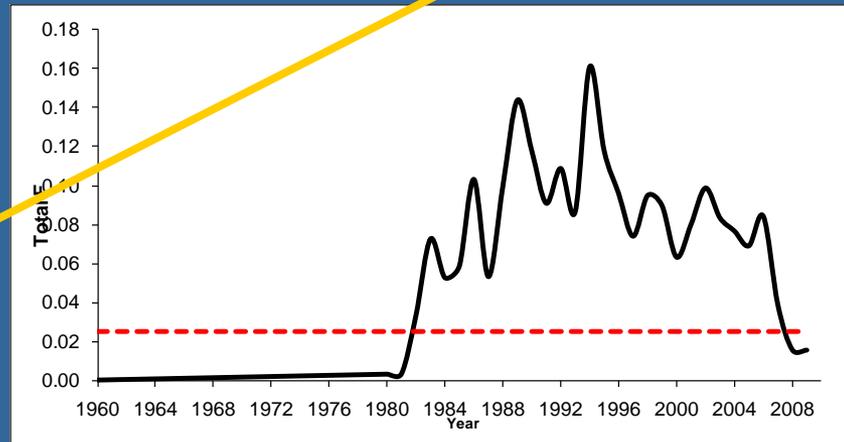


PCGN

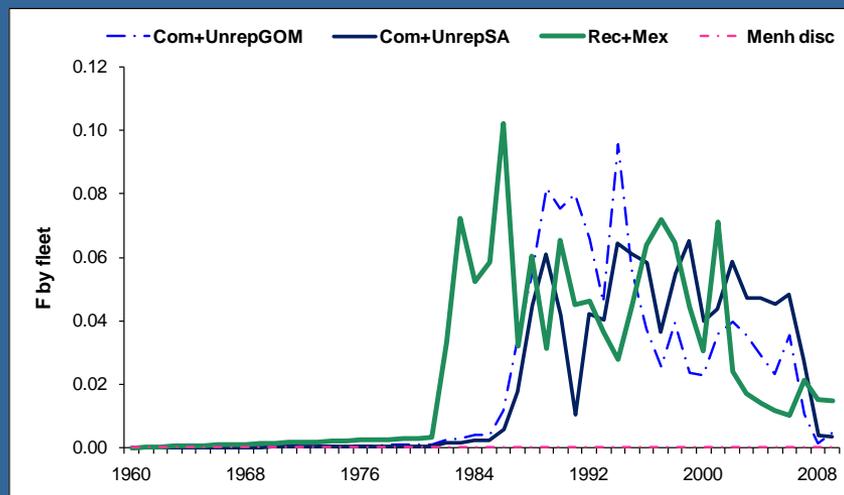
(S1)



F/F_{MSY} and B/B_{MSY}



Total F and F_{MSY}

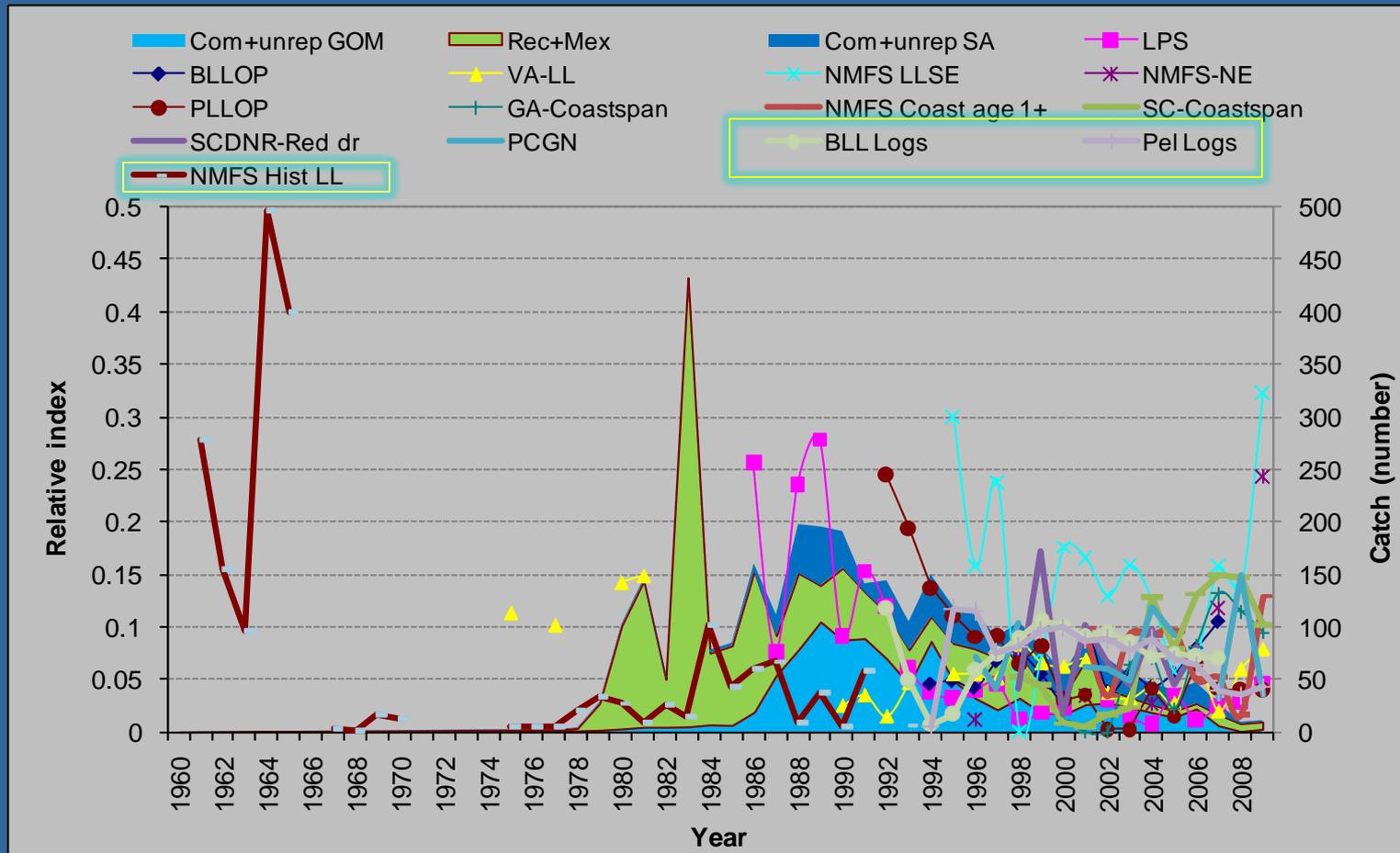


F by fleet

Overfished
since 1995

No overfishing
since 2008

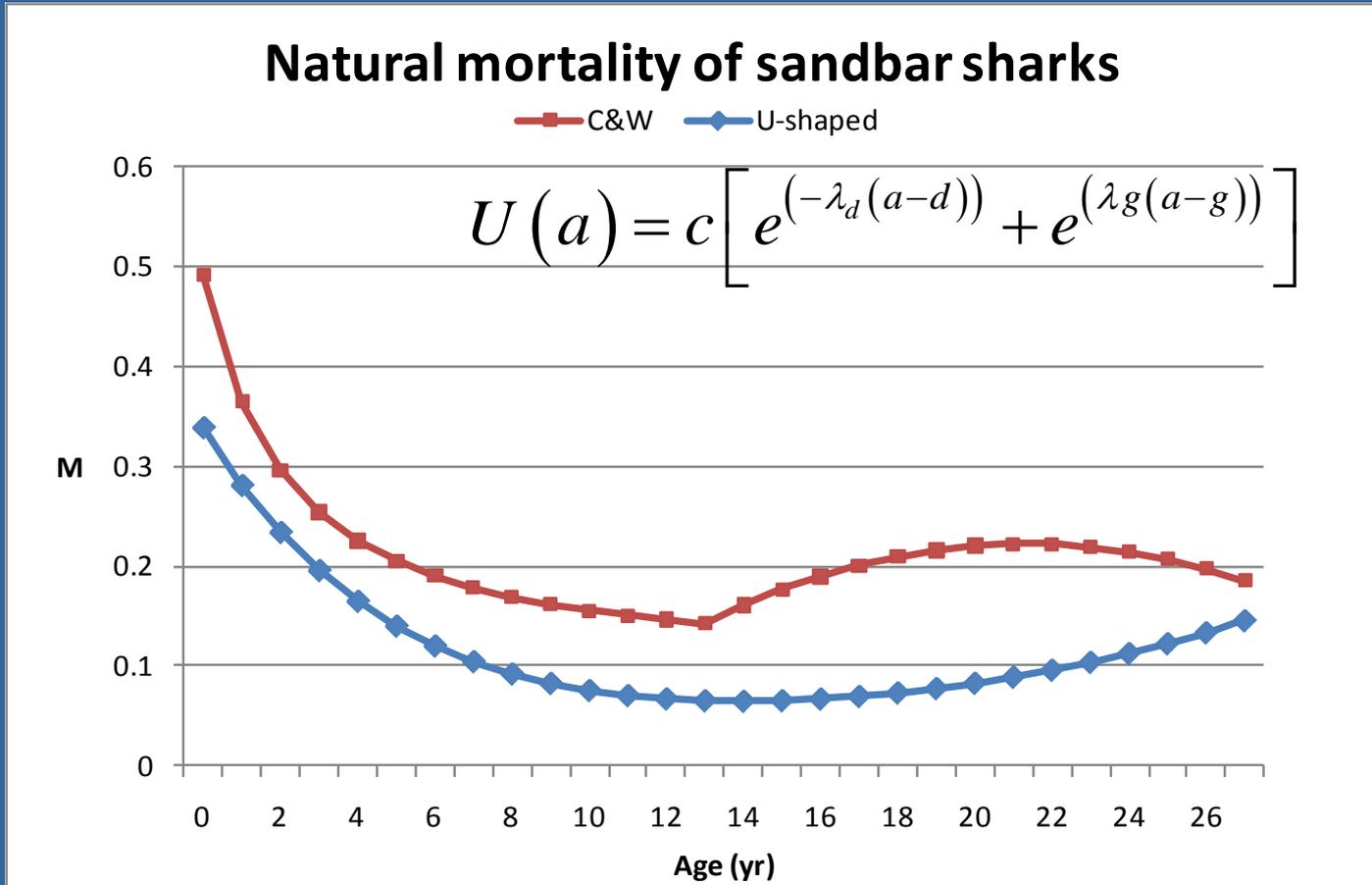
(S2)



5. Summary of all Results

	Base		S1 (inverse CV)		S2 (all indices)		S3 (combined catch)		S4 (comb catch inv CV)		S5 (2-yr cycle)		S6 (3-yr cycle)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	718.01		652.84		767.34		617.71		538.54		717.81		718.71	
Objective function	117.95		85.37		158.18		133.56		93.98		117.85		118.30	
SSF ₂₀₀₉ /SSF _{MSY}	0.66	0.83	0.56	0.70	0.81	0.52	0.78	0.73	0.58	0.73	0.64	0.71	0.66	1.09
F ₂₀₀₉ /F _{MSY}	0.62	0.57	0.62	0.44	0.46	0.52	0.53	0.30	0.61	0.30	0.46	0.55	0.93	0.61
N ₂₀₀₉ /N _{MSY}	0.74	---	0.38	---	0.49	---	0.48	---	0.38	---	0.43	---	0.43	---
MSY	160643	---	264367	---	313002	---	299543	---	252875	---	264927	---	313581	---
SPR _{MSY}	0.78	0.06	0.74	0.09	0.77	0.11	0.79	0.01	0.74	0.01	0.69	0.09	0.86	0.04
F _{MSY}	0.021	---	0.025	---	0.022	---	0.020	---	0.026	---	0.030	---	0.030	---
SSF _{MSY}	477590	---	430320	---	507410	---	509800	---	402450	---	503420	---	503420	---
N _{MSY}	1928165	---	3120188	---	3741763	---	3608844	---	2971324	---	3063451	---	3639906	---
F ₂₀₀₉	0.01	0.57	0.02	0.44	0.01	---	0.01	0.30	0.02	0.30	0.01	0.55	0.01	0.61
SSF ₂₀₀₉	312890	0.60	240950	0.40	410450	0.38	397980	0.37	234890	0.37	319760	0.59	313510	0.63
N ₂₀₀₉	1539102	---	1277408	---	1966818	---	1857216	---	1219683	---	1408804	---	1688767	---
SSF ₂₀₀₉ /SSF ₀	0.28	0.41	0.24	0.27	0.34	0.33	0.35	0.25	0.24	0.25	0.25	0.42	0.32	0.41
B ₂₀₀₉ /B ₀	0.34	0.33	0.30	0.18	0.40	0.27	0.40	0.18	0.30	0.18	0.33	0.33	0.35	0.34
R ₀	563490	0.20	516900	0.14	612910	0.08	587230	0.16	494350	0.16	516810	0.18	612140	0.23
Pup-survival	0.84	0.29	0.94	0.30	0.86	0.00	0.82	0.29	0.94	0.29	0.84	0.29	0.84	0.29
alpha	1.64	---	1.84	---	1.67	---	1.59	---	1.82	---	2.05	---	1.37	---
steepness	0.29	---	0.31	---	0.29	---	0.28	---	0.31	---	0.34	---	0.25	---

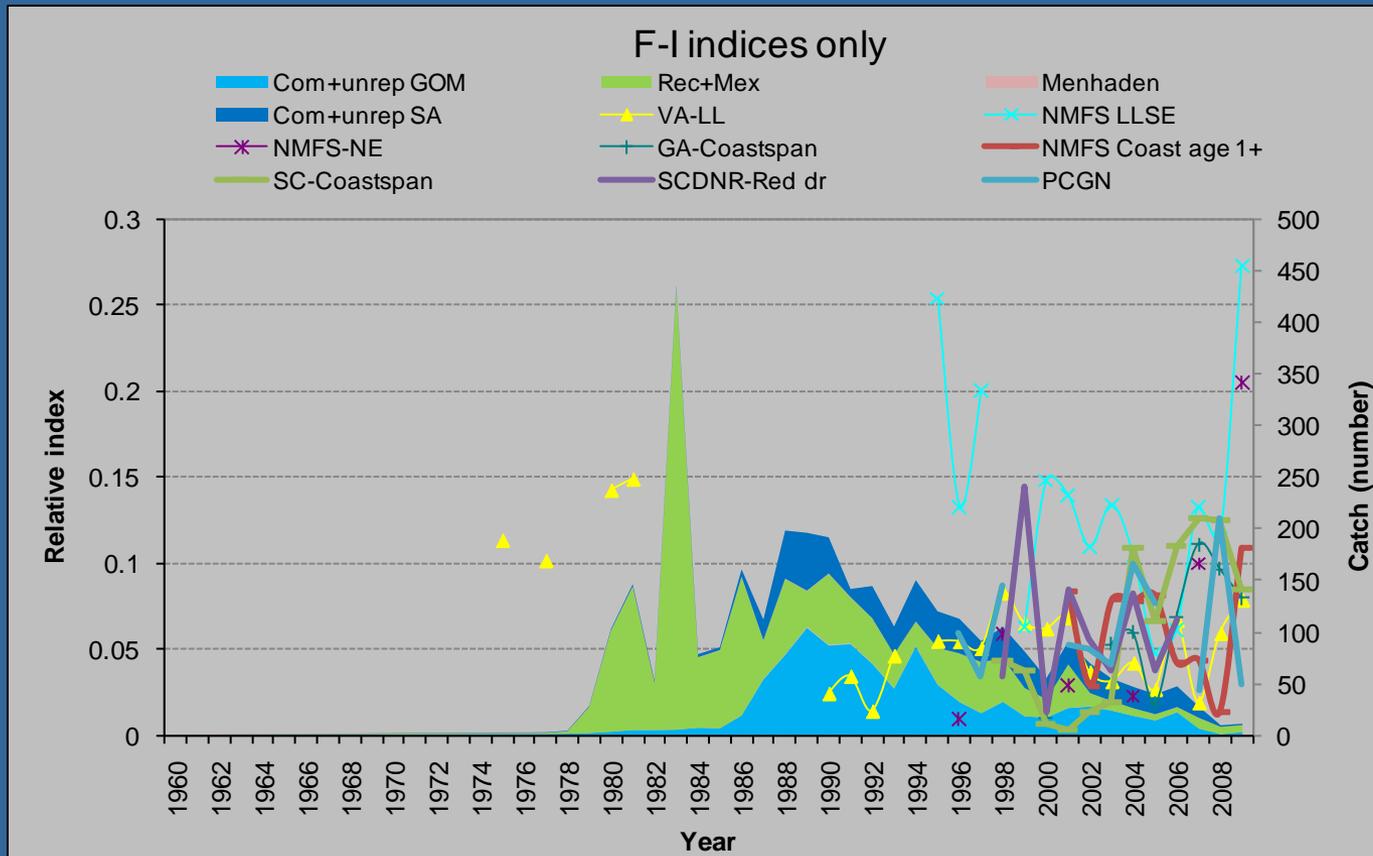
S7: U-shaped M



5. Summary of all Results (continued)

	S7 (U-shaped M)		S8 (F-I indices)		S9 (ranked indices)		S10 (hierarchical ind)		S11 (hier ind, no wt)		S12 (low catch)		S13 (high catch)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	717.40		721.25		791.27		753.73		781.79		712.71		716.79	
Objective function	117.64		93.60		154.58		51.94		65.97		115.30		117.34	
SSF ₂₀₀₉ /SSF _{MSY}	0.57	0.59	1.17	0.83	0.66	0.85	0.61	0.82	0.41	1.07	0.66	0.79	0.77	0.81
F ₂₀₀₉ /F _{MSY}	0.41	0.51	0.26	0.95	0.63	1.02	0.67	0.57	1.14	0.83	0.70	0.57	0.21	0.58
N ₂₀₀₉ /N _{MSY}	0.43	---	0.67	---	0.42	---	0.39	---	0.27	---	0.43	---	0.46	---
MSY	225930	---	427070	---	292289	---	282174	---	252619	---	145726	---	1350123	---
SPR _{MSY}	0.62	0.11	0.78	0.06	0.79	0.05	0.78	0.07	0.79	0.06	0.78	0.07	0.78	0.06
F _{MSY}	0.044	---	0.021	---	0.020	---	0.021	---	0.020	---	0.014	---	0.023	---
SSF _{MSY}	543750	---	721400	---	491570	---	471350	---	418530	---	249020	---	2233800	---
N _{MSY}	2501535	---	5128279	---	3522572	---	3386675	---	3046233	---	1770890	---	16150499	---
F ₂₀₀₉	0.02	0.51	0.01	0.95	0.01	1.02	0.01	0.57	0.02	0.83	0.01	0.57	0.00	0.58
SSF ₂₀₀₉	312140	0.56	841940	1.04	326150	1.07	288810	0.59	172330	0.89	163310	0.62	1722400	0.59
N ₂₀₀₉	1163572	---	3720384	---	1583756	---	1436508	---	900438	---	823421	---	7932433	---
SSF ₂₀₀₉ /SSF ₀	0.22	0.43	0.52	0.50	0.29	0.48	0.27	0.41	0.18	0.71	0.29	0.41	0.33	0.37
B ₂₀₀₉ /B ₀	0.30	0.33	0.56	0.41	0.35	0.42	0.32	0.33	0.23	0.59	0.36	0.32	0.38	0.31
R ₀	439030	0.15	836730	0.55	572880	0.59	552790	0.19	495180	0.19	285570	0.21	2644800	0.22
Pup-survival	0.85	0.29	0.85	0.29	0.83	0.29	0.85	0.29	0.81	0.29	0.86	0.29	0.84	0.29
alpha	2.69	---	1.65	---	1.61	---	1.65	---	1.59	---	1.68	---	1.63	---
steepness	0.40	---	0.29	---	0.29	---	0.29	---	0.28	---	0.30	---	0.29	---

S8: Fishery-independent indices only



5. Summary of all Results (continued)

	S7 (U-shaped M)		S8 (F-I indices)		S9 (ranked indices)		S10 (hierarchical ind)		S11 (hier ind, no wt)		S12 (low catch)		S13 (high catch)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	717.40		721.25		791.27		753.73		781.79		712.71		716.79	
Objective function	117.64		93.60		154.58		51.94		65.97		115.30		117.34	
SSF ₂₀₀₉ /SSF _{MSY}	0.57	0.59	1.17	0.83	0.66	0.85	0.61	0.82	0.41	1.07	0.66	0.79	0.77	0.81
F ₂₀₀₉ /F _{MSY}	0.41	0.51	0.26	0.95	0.63	1.02	0.67	0.57	1.14	0.83	0.70	0.57	0.21	0.58
N ₂₀₀₉ /N _{MSY}	0.43	---	0.67	---	0.42	---	0.39	---	0.27	---	0.43	---	0.46	---
MSY	225930	---	427070	---	292289	---	282174	---	252619	---	145726	---	1350123	---
SPR _{MSY}	0.62	0.11	0.78	0.06	0.79	0.05	0.78	0.07	0.79	0.06	0.78	0.07	0.78	0.06
F _{MSY}	0.044	---	0.021	---	0.020	---	0.021	---	0.020	---	0.014	---	0.023	---
SSF _{MSY}	543750	---	721400	---	491570	---	471350	---	418530	---	249020	---	2233800	---
N _{MSY}	2501535	---	5128279	---	3522572	---	3386675	---	3046233	---	1770890	---	16150499	---
F ₂₀₀₉	0.02	0.51	0.01	0.95	0.01	1.02	0.01	0.57	0.02	0.83	0.01	0.57	0.00	0.58
SSF ₂₀₀₉	312140	0.56	841940	1.04	326150	1.07	288810	0.59	172330	0.89	163310	0.62	1722400	0.59
N ₂₀₀₉	1163572	---	3720384	---	1583756	---	1436508	---	900438	---	823421	---	7932433	---
SSF ₂₀₀₉ /SSF ₀	0.22	0.43	0.52	0.50	0.29	0.48	0.27	0.41	0.18	0.71	0.29	0.41	0.33	0.37
B ₂₀₀₉ /B ₀	0.30	0.33	0.56	0.41	0.35	0.42	0.32	0.33	0.23	0.59	0.36	0.32	0.38	0.31
R ₀	439030	0.15	836730	0.55	572880	0.59	552790	0.19	495180	0.19	285570	0.21	2644800	0.22
Pup-survival	0.85	0.29	0.85	0.29	0.83	0.29	0.85	0.29	0.81	0.29	0.86	0.29	0.84	0.29
alpha	2.69	---	1.65	---	1.61	---	1.65	---	1.59	---	1.68	---	1.63	---
steepness	0.40	---	0.29	---	0.29	---	0.29	---	0.28	---	0.30	---	0.29	---

S9: Rank-based weighting of indices

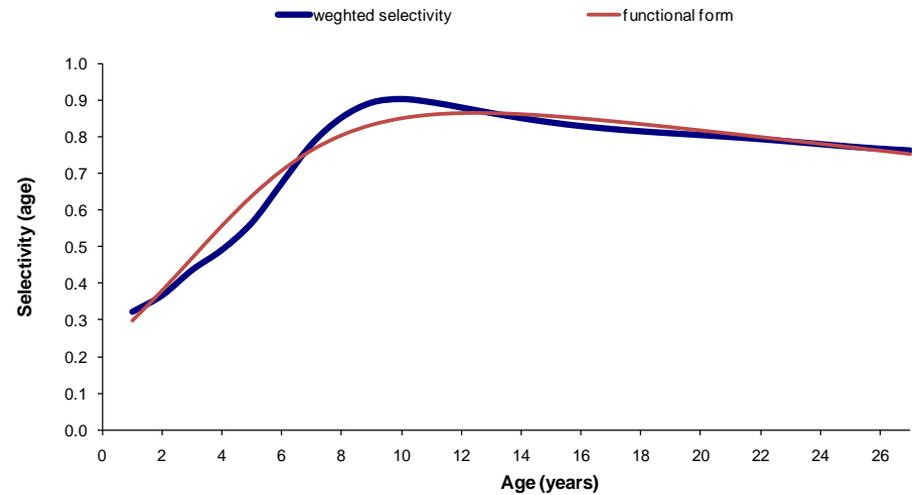
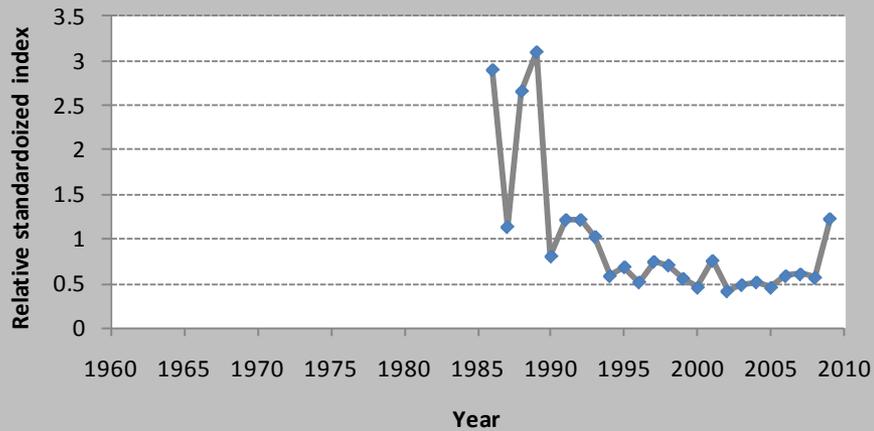
- LPS: 5 (=downweighted by 5)
- GA Coastspan, PCGN: 4
- SC Coastspan, SC Red drum historic: 3
- BLLOP, VA-LL, NMFS Coastspan Age 1+, NMFS LL NE, PLLOP: 2
- NMFS LL SE: 1

5. Summary of all Results (continued)

	S7 (U-shaped M)		S8 (F-I indices)		S9 (ranked indices)		S10 (hierarchical ind)		S11 (hier ind, no wt)		S12 (low catch)		S13 (high catch)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	717.40		721.25		791.27		753.73		781.79		712.71		716.79	
Objective function	117.64		93.60		154.58		51.94		65.97		115.30		117.34	
SSF ₂₀₀₉ /SSF _{MSY}	0.57	0.59	1.17	0.83	0.66	0.85	0.61	0.82	0.41	1.07	0.66	0.79	0.77	0.81
F ₂₀₀₉ /F _{MSY}	0.41	0.51	0.26	0.95	0.63	1.02	0.67	0.57	1.14	0.83	0.70	0.57	0.21	0.58
N ₂₀₀₉ /N _{MSY}	0.43	---	0.67	---	0.42	---	0.39	---	0.27	---	0.43	---	0.46	---
MSY	225930	---	427070	---	292289	---	282174	---	252619	---	145726	---	1350123	---
SPR _{MSY}	0.62	0.11	0.78	0.06	0.79	0.05	0.78	0.07	0.79	0.06	0.78	0.07	0.78	0.06
F _{MSY}	0.044	---	0.021	---	0.020	---	0.021	---	0.020	---	0.014	---	0.023	---
SSF _{MSY}	543750	---	721400	---	491570	---	471350	---	418530	---	249020	---	2233800	---
N _{MSY}	2501535	---	5128279	---	3522572	---	3386675	---	3046233	---	1770890	---	16150499	---
F ₂₀₀₉	0.02	0.51	0.01	0.95	0.01	1.02	0.01	0.57	0.02	0.83	0.01	0.57	0.00	0.58
SSF ₂₀₀₉	312140	0.56	841940	1.04	326150	1.07	288810	0.59	172330	0.89	163310	0.62	1722400	0.59
N ₂₀₀₉	1163572	---	3720384	---	1583756	---	1436508	---	900438	---	823421	---	7932433	---
SSF ₂₀₀₉ /SSF ₀	0.22	0.43	0.52	0.50	0.29	0.48	0.27	0.41	0.18	0.71	0.29	0.41	0.33	0.37
B ₂₀₀₉ /B ₀	0.30	0.33	0.56	0.41	0.35	0.42	0.32	0.33	0.23	0.59	0.36	0.32	0.38	0.31
R ₀	439030	0.15	836730	0.55	572880	0.59	552790	0.19	495180	0.19	285570	0.21	2644800	0.22
Pup-survival	0.85	0.29	0.85	0.29	0.83	0.29	0.85	0.29	0.81	0.29	0.86	0.29	0.84	0.29
alpha	2.69	---	1.65	---	1.61	---	1.65	---	1.59	---	1.68	---	1.63	---
steepness	0.40	---	0.29	---	0.29	---	0.29	---	0.28	---	0.30	---	0.29	---

S10, S11: Hierarchical index

Hierarchical index



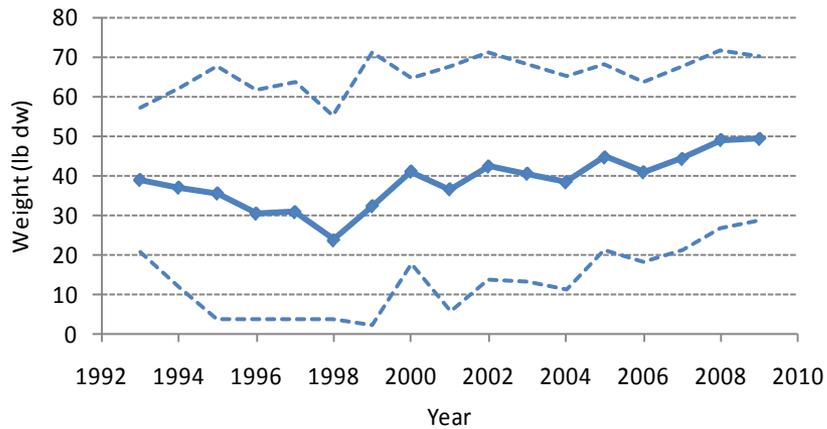
5. Summary of all Results (continued)

	S7 (U-shaped M)		S8 (F-I indices)		S9 (ranked indices)		S10 (hierarchical ind)		S11 (hier ind, no wt)		S12 (low catch)		S13 (high catch)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	717.40		721.25		791.27		753.73		781.79		712.71		716.79	
Objective function	117.64		93.60		154.58		51.94		65.97		115.30		117.34	
SSF ₂₀₀₉ /SSF _{MSY}	0.57	0.59	1.17	0.83	0.66	0.85	0.61	0.82	0.41	1.07	0.66	0.79	0.77	0.81
F ₂₀₀₉ /F _{MSY}	0.41	0.51	0.26	0.95	0.63	1.02	0.67	0.57	1.14	0.83	0.70	0.57	0.21	0.58
N ₂₀₀₉ /N _{MSY}	0.43	---	0.67	---	0.42	---	0.39	---	0.27	---	0.43	---	0.46	---
MSY	225930	---	427070	---	292289	---	282174	---	252619	---	145726	---	1350123	---
SPR _{MSY}	0.62	0.11	0.78	0.06	0.79	0.05	0.78	0.07	0.79	0.06	0.78	0.07	0.78	0.06
F _{MSY}	0.044	---	0.021	---	0.020	---	0.021	---	0.020	---	0.014	---	0.023	---
SSF _{MSY}	543750	---	721400	---	491570	---	471350	---	418530	---	249020	---	2233800	---
N _{MSY}	2501535	---	5128279	---	3522572	---	3386675	---	3046233	---	1770890	---	16150499	---
F ₂₀₀₉	0.02	0.51	0.01	0.95	0.01	1.02	0.01	0.57	0.02	0.83	0.01	0.57	0.00	0.58
SSF ₂₀₀₉	312140	0.56	841940	1.04	326150	1.07	288810	0.59	172330	0.89	163310	0.62	1722400	0.59
N ₂₀₀₉	1163572	---	3720384	---	1583756	---	1436508	---	900438	---	823421	---	7932433	---
SSF ₂₀₀₉ /SSF ₀	0.22	0.43	0.52	0.50	0.29	0.48	0.27	0.41	0.18	0.71	0.29	0.41	0.33	0.37
B ₂₀₀₉ /B ₀	0.30	0.33	0.56	0.41	0.35	0.42	0.32	0.33	0.23	0.59	0.36	0.32	0.38	0.31
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alpha	2.69	---	1.65	---	1.61	---	1.65	---	1.59	---	1.68	---	1.63	---
steepness	0.40	---	0.29	---	0.29	---	0.29	---	0.28	---	0.30	---	0.29	---

S12, S13: Low and high catches

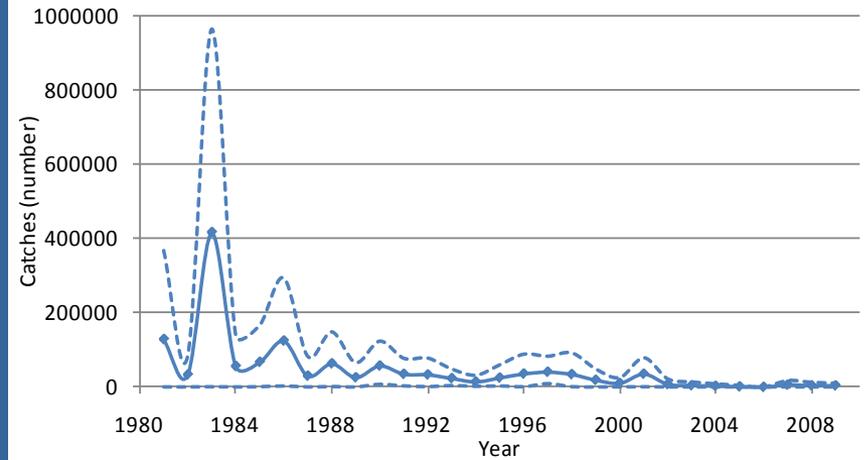
Average weights of sandbar sharks (BLLOP)

—◆— PREDWT - - - LOWER95 - - - UPPER95

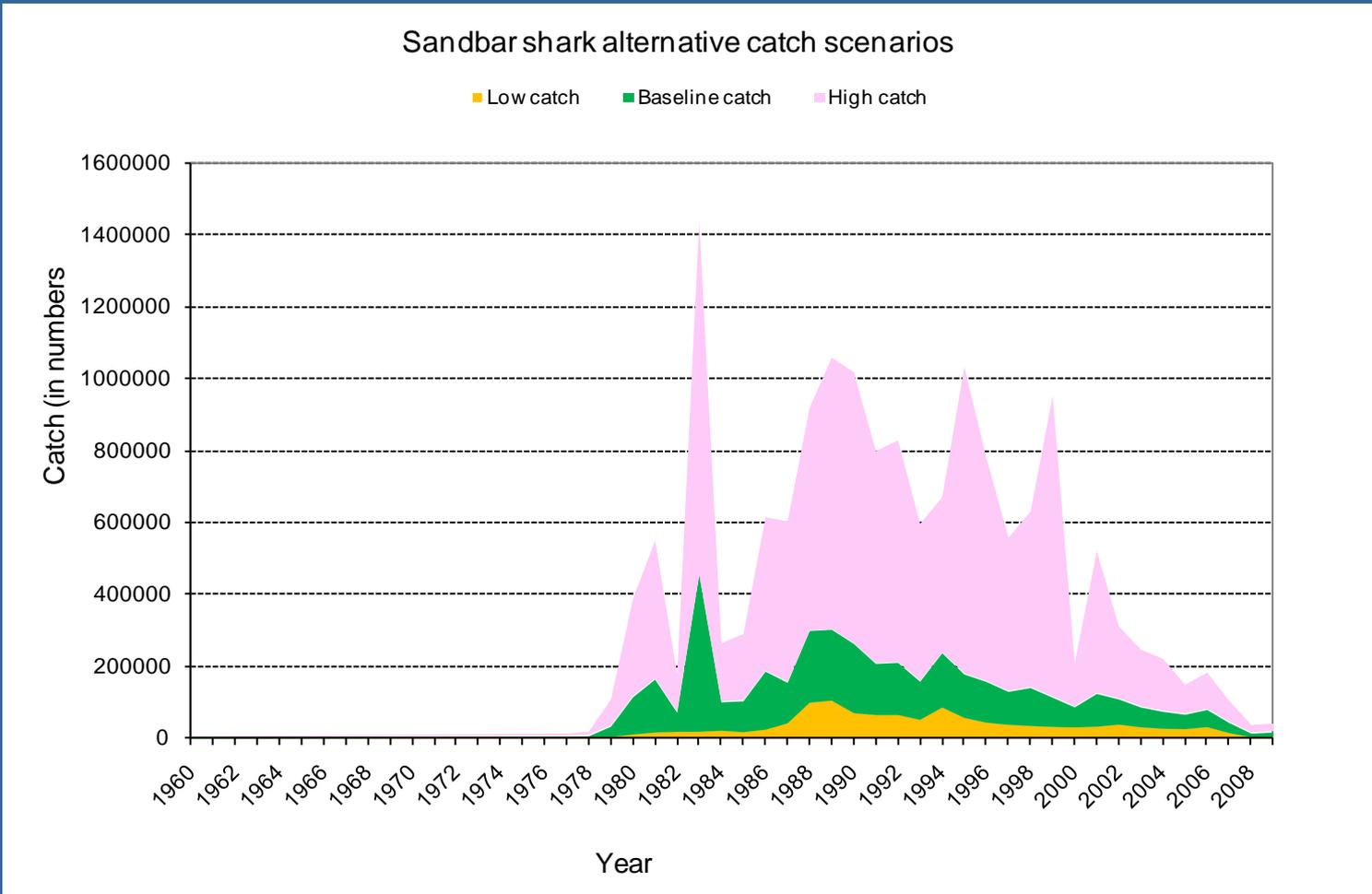


Recreational catches of sandbar sharks

—◆— ab1 - - - lower95%CL - - - upper95%CL



S12, S13: Low and high catches (continued)



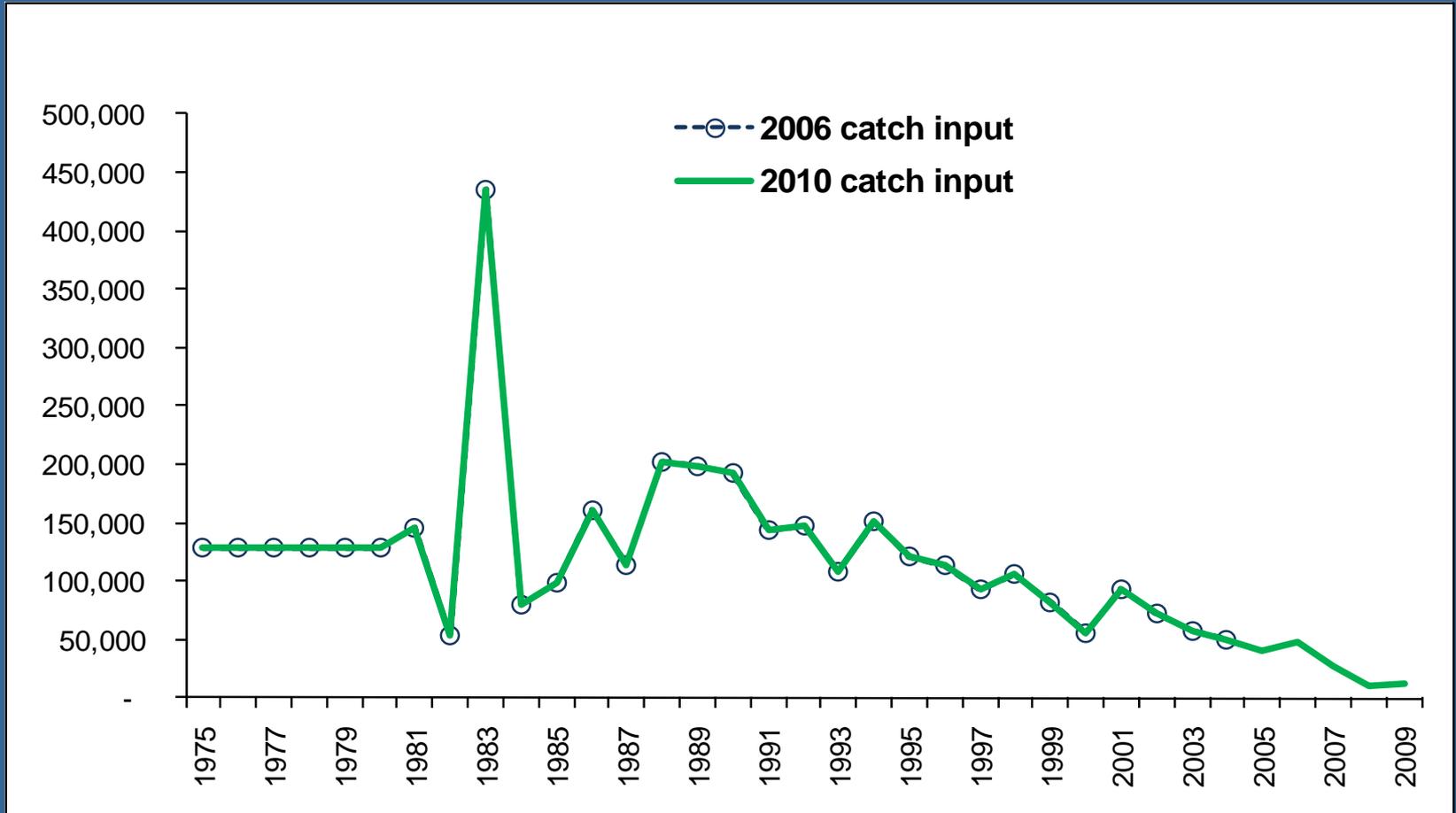
5. Summary of all Results (continued)

	S7 (U-shaped M)		S8 (F-I indices)		S9 (ranked indices)		S10 (hierarchical ind)		S11 (hier ind, no wt)		S12 (low catch)		S13 (high catch)	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	717.40		721.25		791.27		753.73		781.79		712.71		716.79	
Objective function	117.64		93.60		154.58		51.94		65.97		115.30		117.34	
SSF ₂₀₀₉ /SSF _{MSY}	0.57	0.59	1.17	0.83	0.66	0.85	0.61	0.82	0.41	1.07	0.66	0.79	0.77	0.81
F ₂₀₀₉ /F _{MSY}	0.41	0.51	0.26	0.95	0.63	1.02	0.67	0.57	1.14	0.83	0.70	0.57	0.21	0.58
N ₂₀₀₉ /N _{MSY}	0.43	---	0.67	---	0.42	---	0.39	---	0.27	---	0.43	---	0.46	---
MSY	225930	---	427070	---	292289	---	282174	---	252619	---	145726	---	1350123	---
SPR _{MSY}	0.62	0.11	0.78	0.06	0.79	0.05	0.78	0.07	0.79	0.06	0.78	0.07	0.78	0.06
F _{MSY}	0.044	---	0.021	---	0.020	---	0.021	---	0.020	---	0.014	---	0.023	---
SSF _{MSY}	543750	---	721400	---	491570	---	471350	---	418530	---	249020	---	2233800	---
N _{MSY}	2501535	---	5128279	---	3522572	---	3386675	---	3046233	---	1770890	---	16150499	---
F ₂₀₀₉	0.02	0.51	0.01	0.95	0.01	1.02	0.01	0.57	0.02	0.83	0.01	0.57	0.00	0.58
SSF ₂₀₀₉	312140	0.56	841940	1.04	326150	1.07	288810	0.59	172330	0.89	163310	0.62	1722400	0.59
N ₂₀₀₉	1163572	---	3720384	---	1583756	---	1436508	---	900438	---	823421	---	7932433	---
SSF ₂₀₀₉ /SSF ₀	0.22	0.43	0.52	0.50	0.29	0.48	0.27	0.41	0.18	0.71	0.29	0.41	0.33	0.37
B ₂₀₀₉ /B ₀	0.30	0.33	0.56	0.41	0.35	0.42	0.32	0.33	0.23	0.59	0.36	0.32	0.38	0.31
R ₀	439030	0.15	836730	0.55	572880	0.59	552790	0.19	495180	0.19	285570	0.21	2644800	0.22
Pup-survival	0.85	0.29	0.85	0.29	0.83	0.29	0.85	0.29	0.81	0.29	0.86	0.29	0.84	0.29
alpha	2.69	---	1.65	---	1.61	---	1.65	---	1.59	---	1.68	---	1.63	---
steepness	0.40	---	0.29	---	0.29	---	0.29	---	0.28	---	0.30	---	0.29	---

6. Continuity analysis

- Used model from 2006
- Used same catches up to 2004, updated for 2005-2009
- Used same indices (*but 7 of 8 reanalyzed*)
- Used same selectivities
- Used 2006 biological parameters
- All same assumptions

Catches

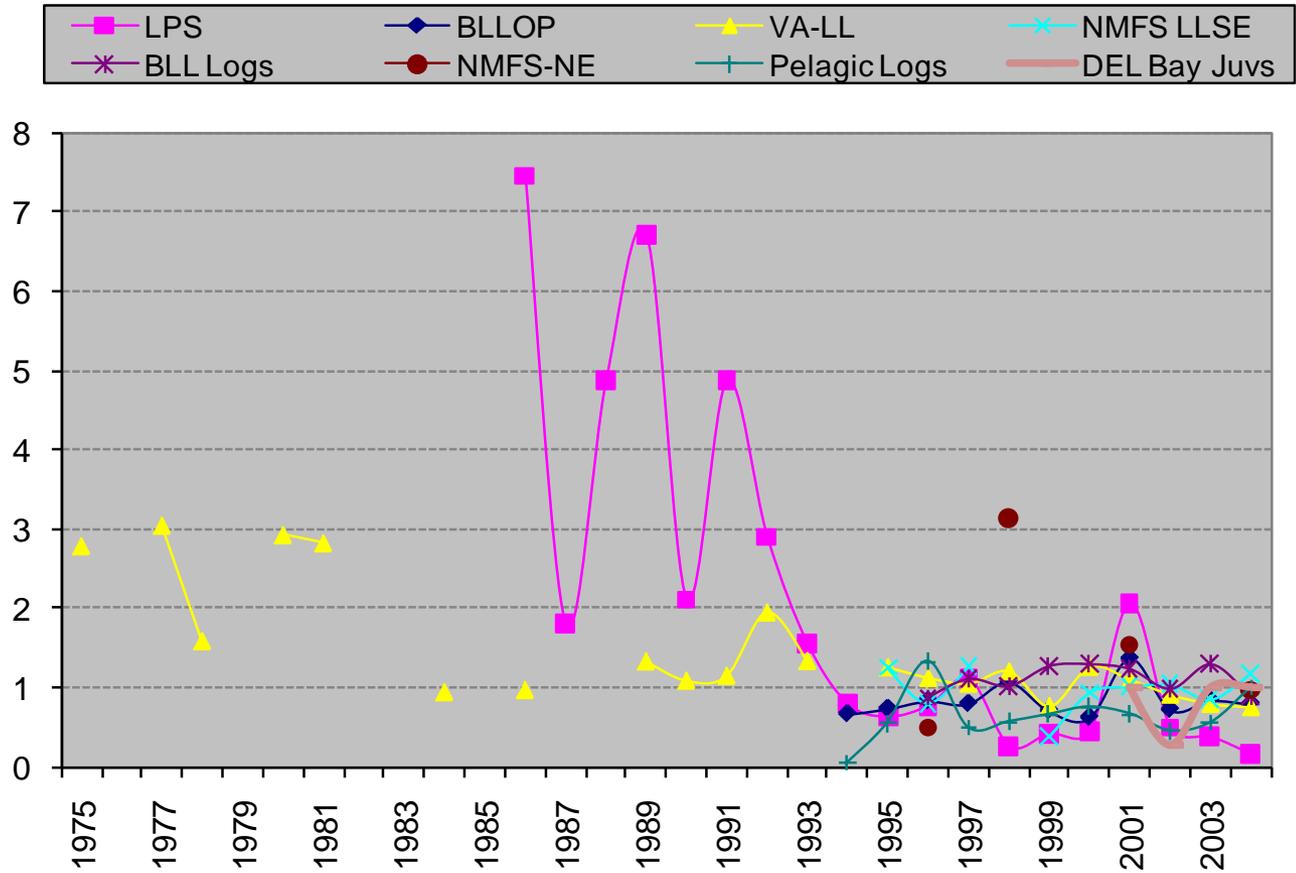


Fishery Inputs

- Indices of Abundance: same as in 2006, but 7 of 8 have been reanalyzed
 - LPS, BLLOP, VA-LL, NMFS LL SE, *DEL Bay Juveniles*, BLL Logs, NMFS LL NE, Pelagic Log,

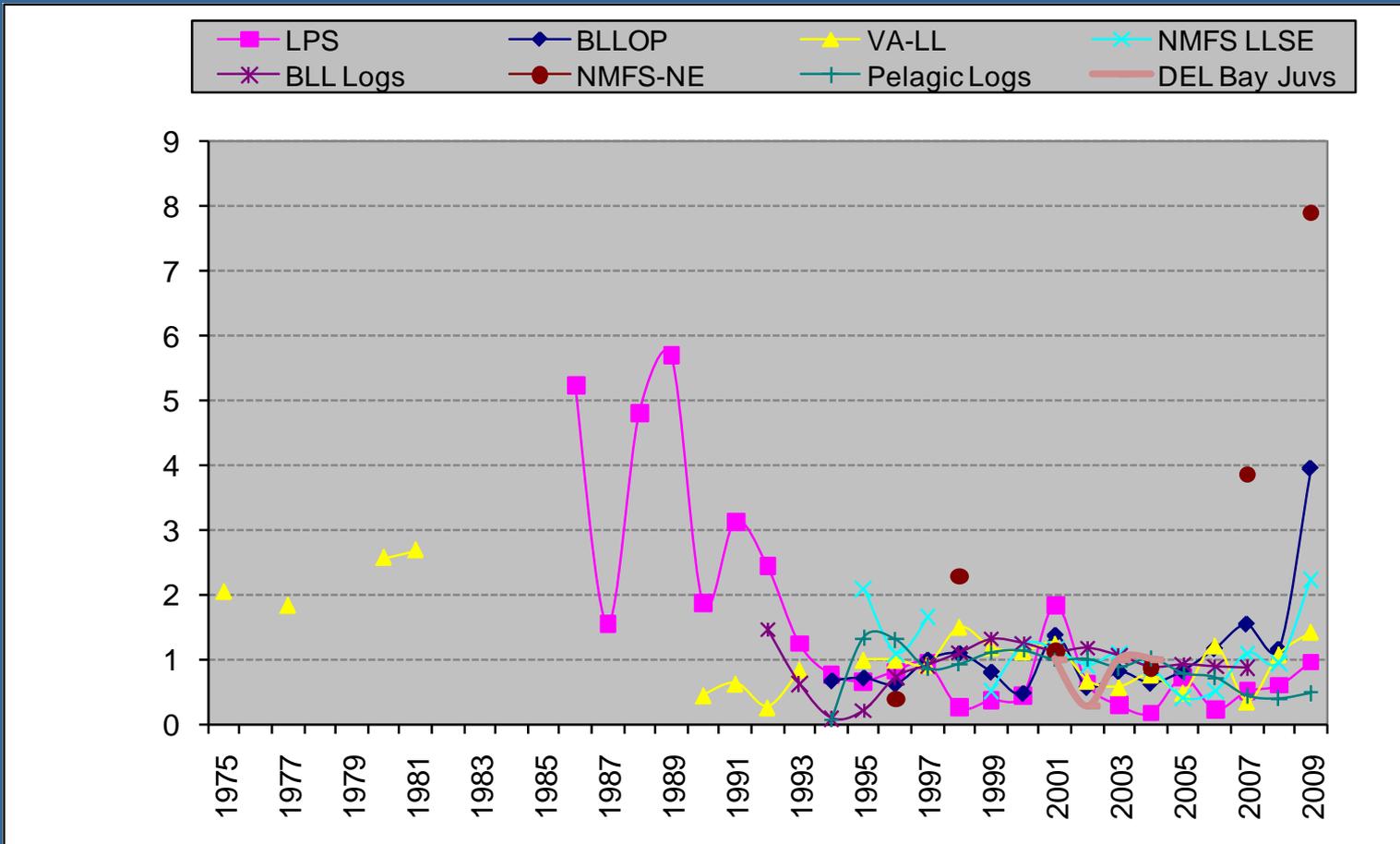
INDICES

2006



INDICES

2010 continuity



Base model Results

2006 base run

2010 continuity

(data to 2004)

(data to 2009)

■ $SSF_{2004 \text{ or } 2009} / SSF_{MSY} =$	0.72		0.80
■ $F_{2004 \text{ or } 2009} / F_{MSY} =$	3.72		0.37
■ Steepness =	0.32		0.37
■ $SPR_{MSY} =$	0.73	NO OVERFISHING	0.70
■ $F_{MSY} =$	0.015		0.055

OVERFISHED



Model changes in 2010 at a glance: (vs. 2006)

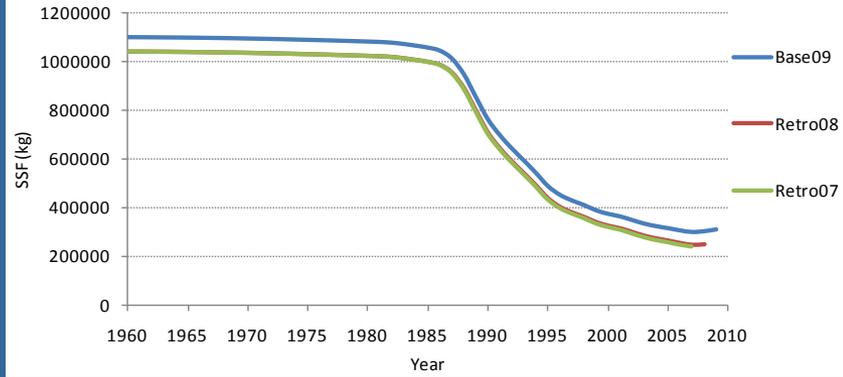
- Model starts in 1960 (1975)
- Catches span 1960-2009; commercial catches split into GOM and SA (1 commercial series)
- CPUE indices: 11 indices, 5 new, all reanalyzed (8 indices)
- New selectivities:
 - 4 for catch (3)
 - 8 for indices (2)

Model changes in 2010 at a glance: (vs. 2006)

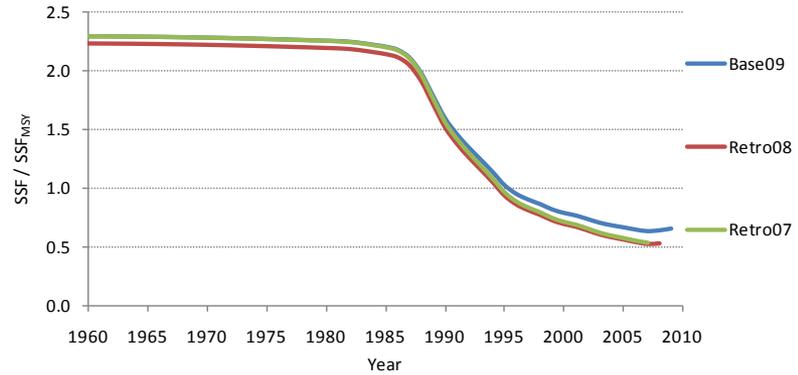
- New biological parameters:
 - Age and growth curve with $K=0.12$ (0.09)
 - Lifespan of 27 years (40)
 - Maturity ogive with $a_{50}=13$ (19)
 - Litter size relationship (constant)
 - Parturition frequency of 2.5 years (biennial)
 - New M values

7. Retrospective analyses

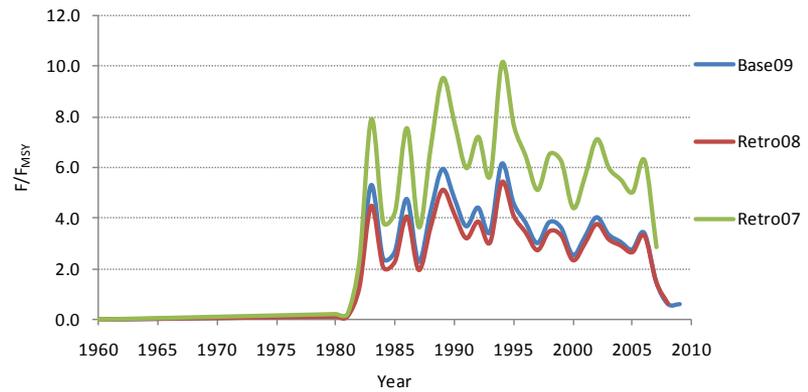
Retrospective plots of SSF



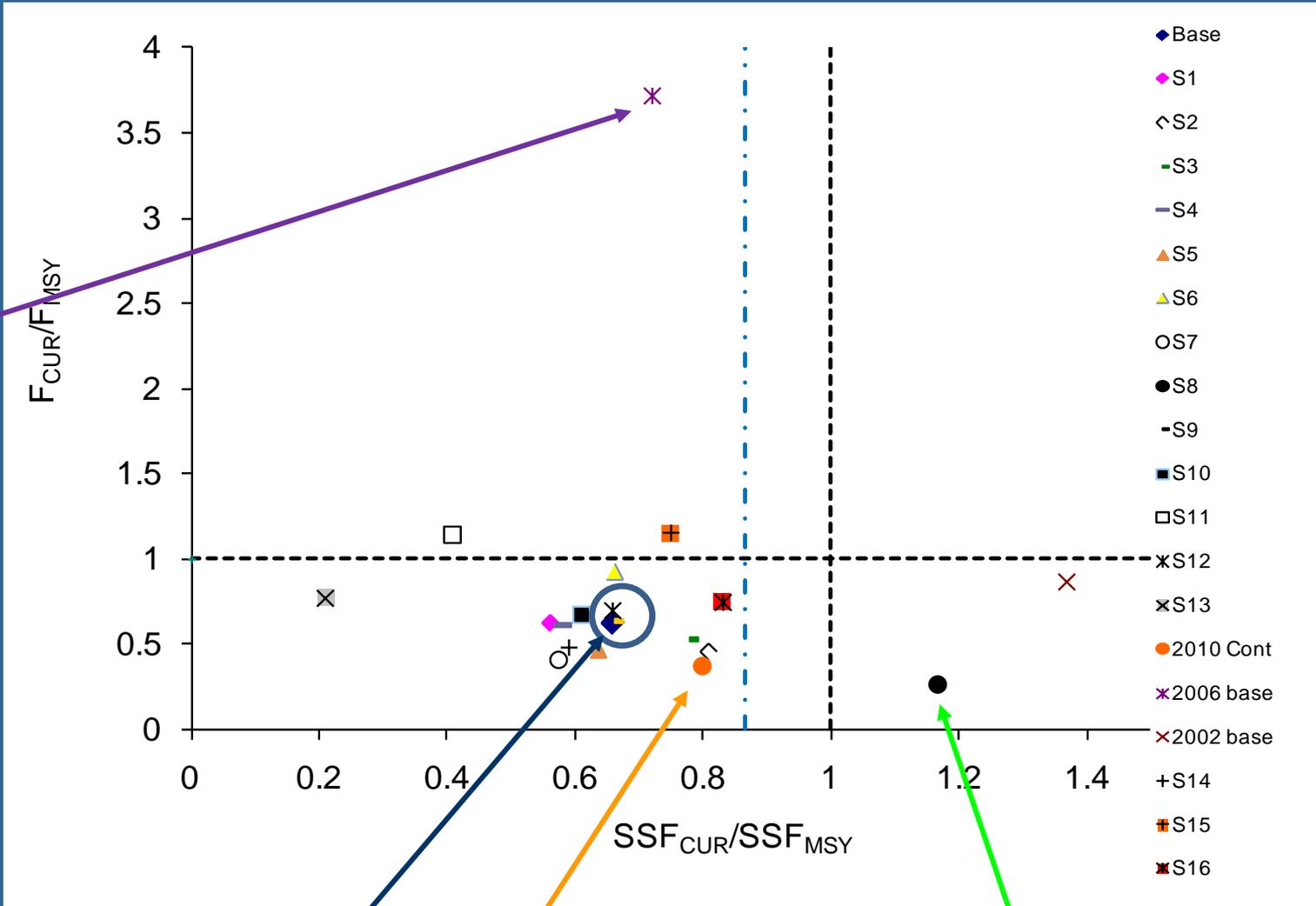
Retrospective plots of SSF/SSF_{MSY}



Retrospective plots of F/F_{MSY}



Phase plots of all results

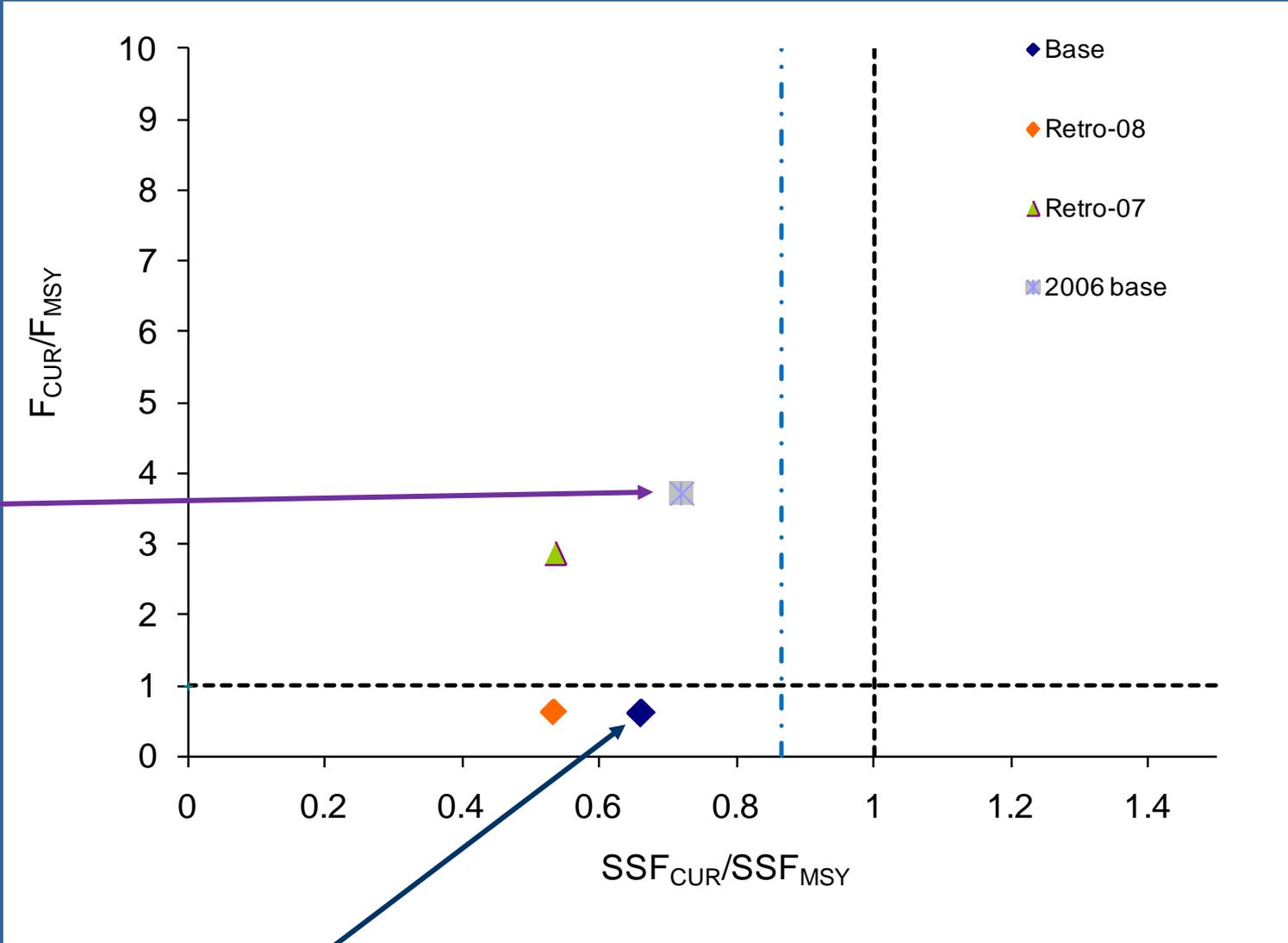


BASE 2006

BASE 2010

Continuity

F-I indices only



BASE 2006

BASE 2010

8. Stock projections

- Projections with Pro-2Box (Porch 2003)
- Allow for process error in stock-recruit relationship
- Use bootstrapping
- F and TAC based projection scenarios as per guidance from HMS

Projection scenarios: F-based

- 1) Project with $F=0$ and determine year when probability of stock having recovered ($SSF/SSF_{msy} > 1$) is 70%
- 2) If that year is >10 , add 1 generation time to the rebuilding timeframe
- 3) Generation time (20 years) computed as:

$$GenTime = \frac{\sum_i i f_i \prod_{j=1}^{i-1} s_j}{\sum_i f_i \prod_{j=1}^{i-1} s_j}$$

Projection scenarios: F- and TAC-based

- 4) Find F and TAC strategies that will allow rebuilding by the new year with a probability of 50% and 70%
- 5) Management starts in 2013; in interim years (2010-2012) $F = F_{2009}$ and $TAC = \text{mean of catches in 2008 and 2009}$
- 6) Calculate also the probability of rebuilding by 2070 (the present rebuilding time horizon) with $F = F_{2009}$ and $TAC = 220 \text{ mt ww}$

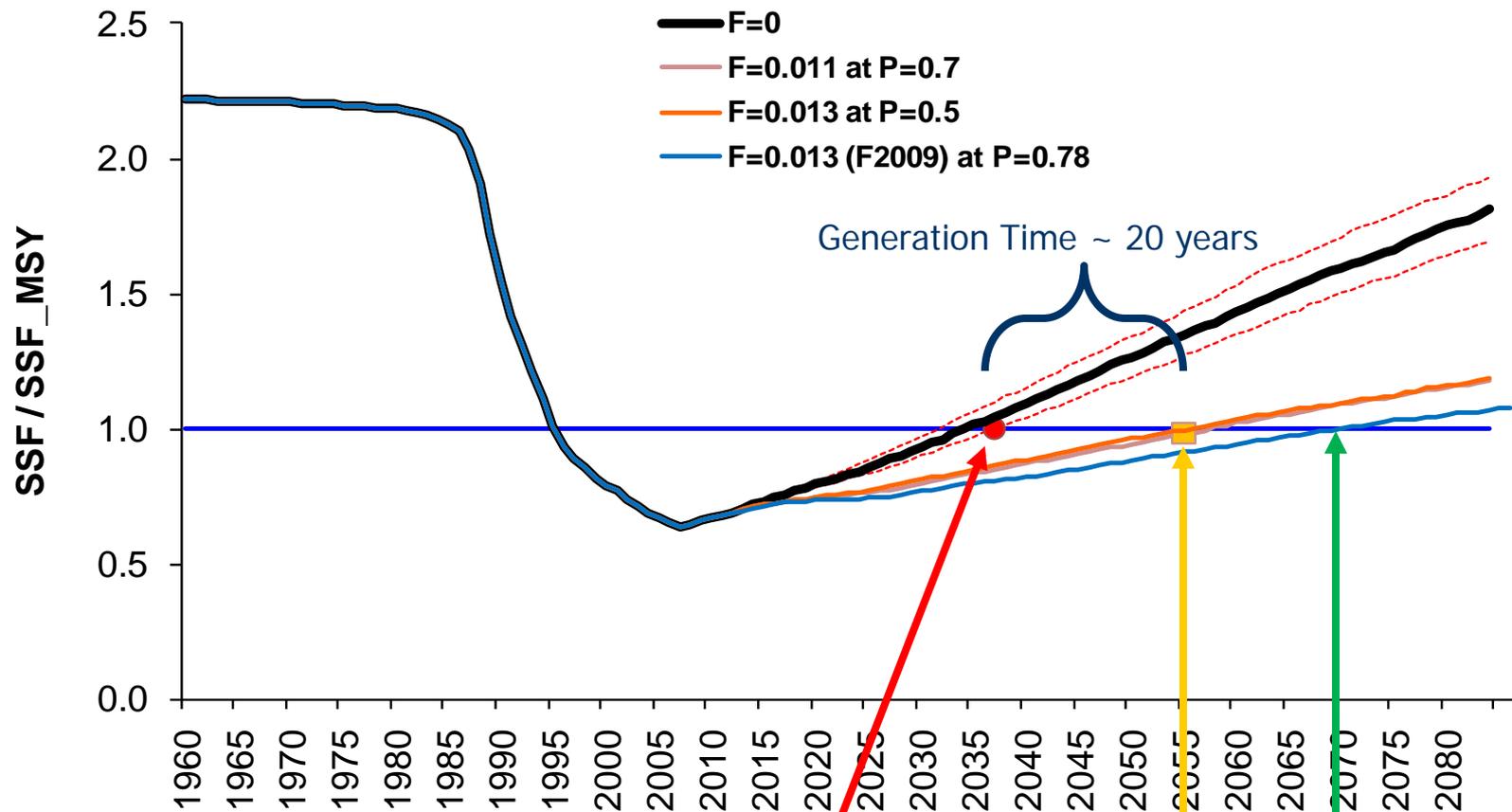
Conversion of mean catches in numbers to weight for interim years (2010-2012)

Catches are in numbers and TAC is based on weight

Catch by sector in numbers				
	Com+Un	Rec+Mex	Menh disc	Total
2008	2153	7324	374	9851
2009	3986	7026	374	11386

Used average weights from BLLOP for 2008 and 2009, MRFSS (2000-2009), and menhaden discards

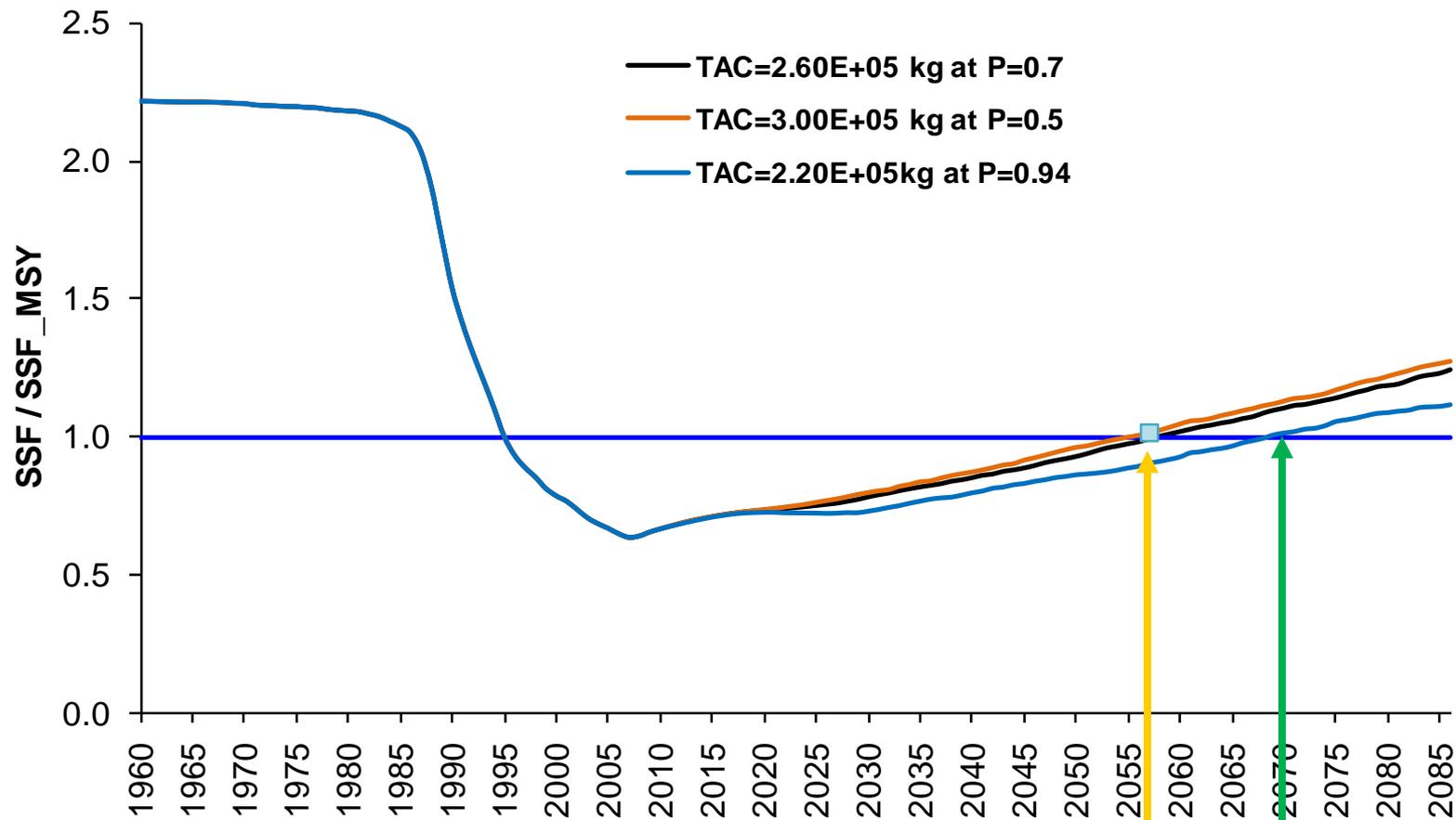
Catch by sector in weight (lb dw)				
Com+Un	Rec+Mex	Menh disc	Total	Total (mt ww)
105,880	105,522	3092	214,494	195
197,152	101,228	3092	301,472	273
				234 mean



70th percentile to rebuild
with F=0 (year 2038)

Rebuilding target
(year 2058)

Old rebuilding target
(year 2070)

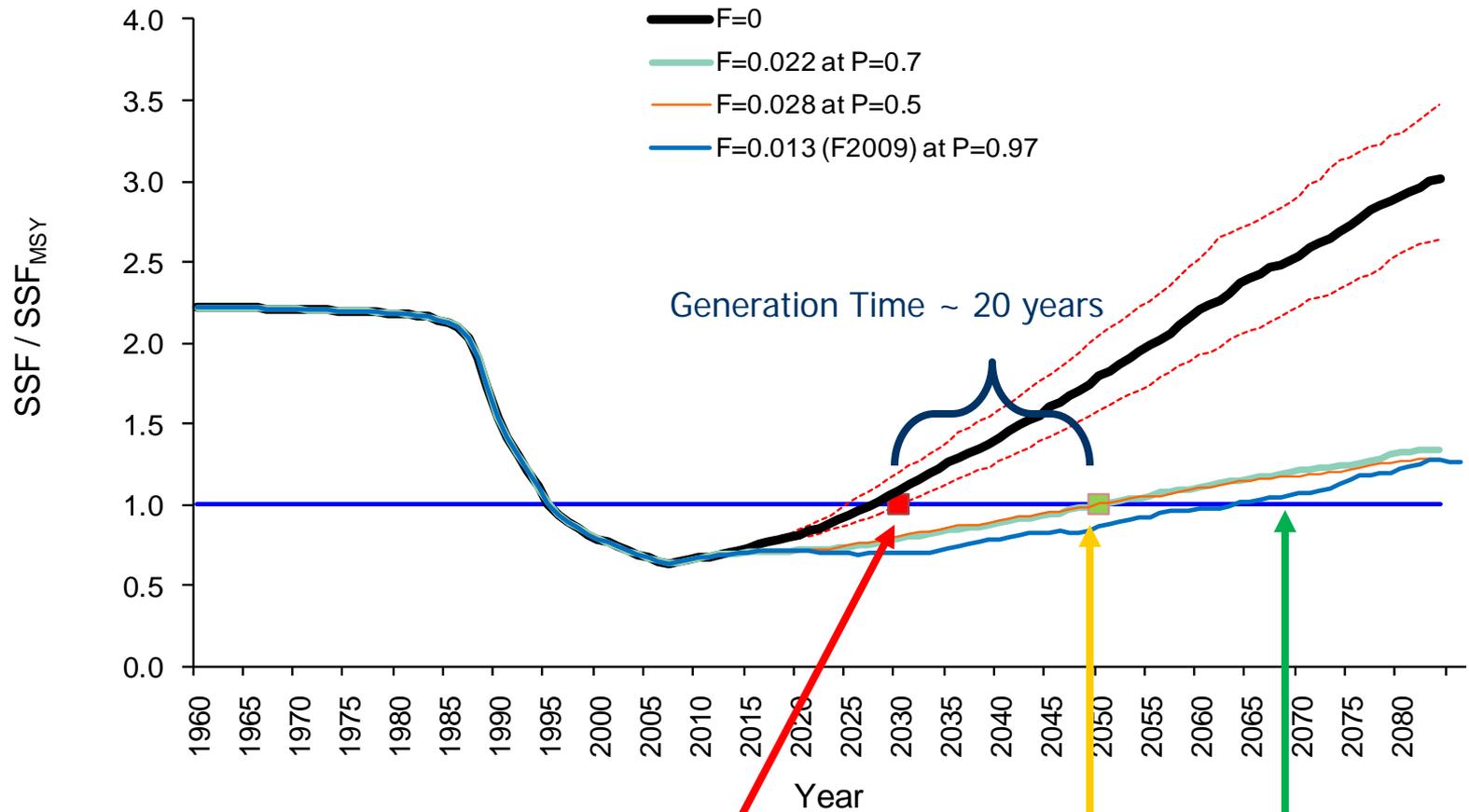


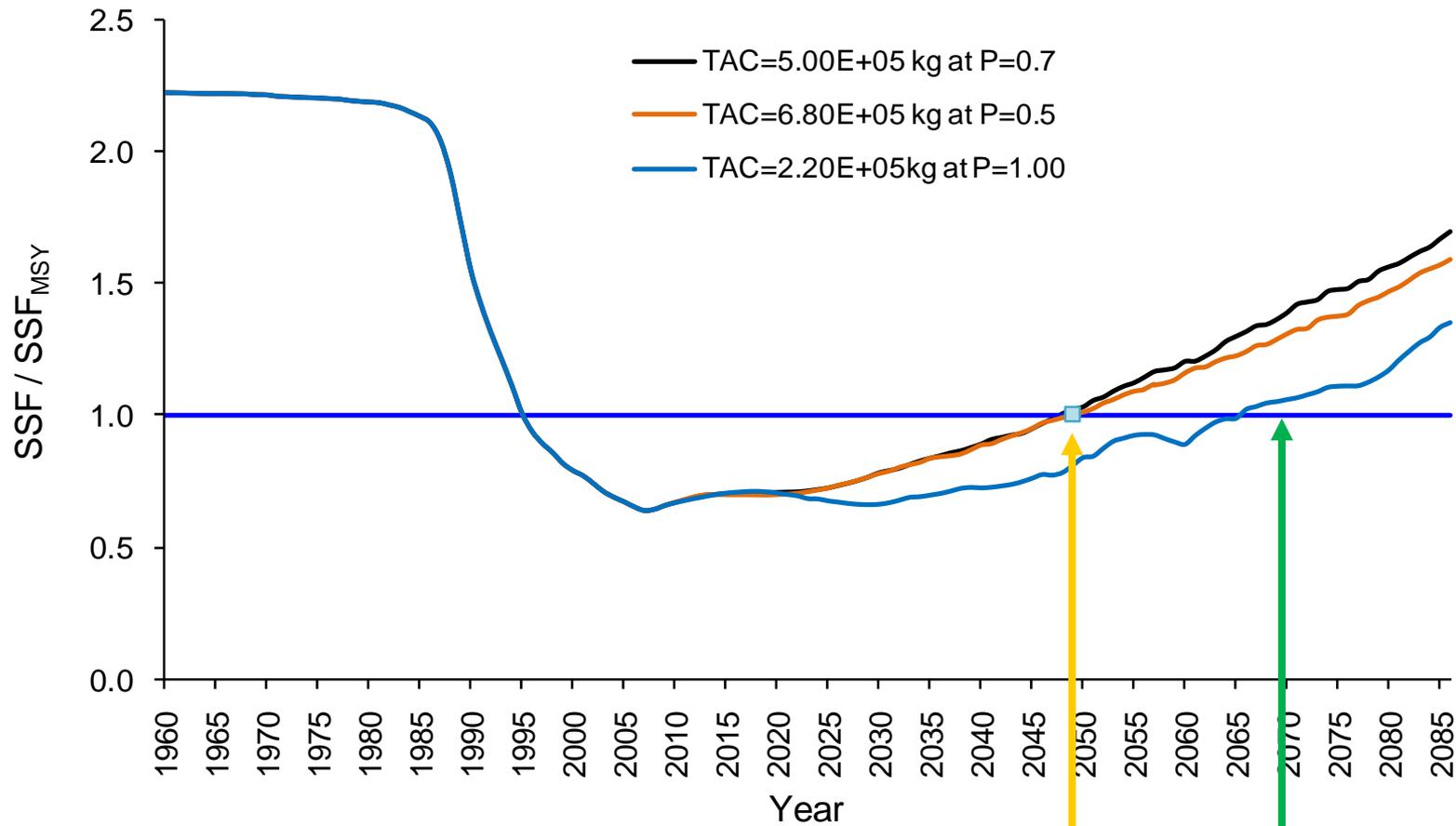
Rebuilding target
(year 2058)

Old rebuilding target
(year 2070)

Projection scenarios: varying SD of recruitment deviations

- 1) SD of recruitment deviations was doubled (from 0.4 to 0.8)



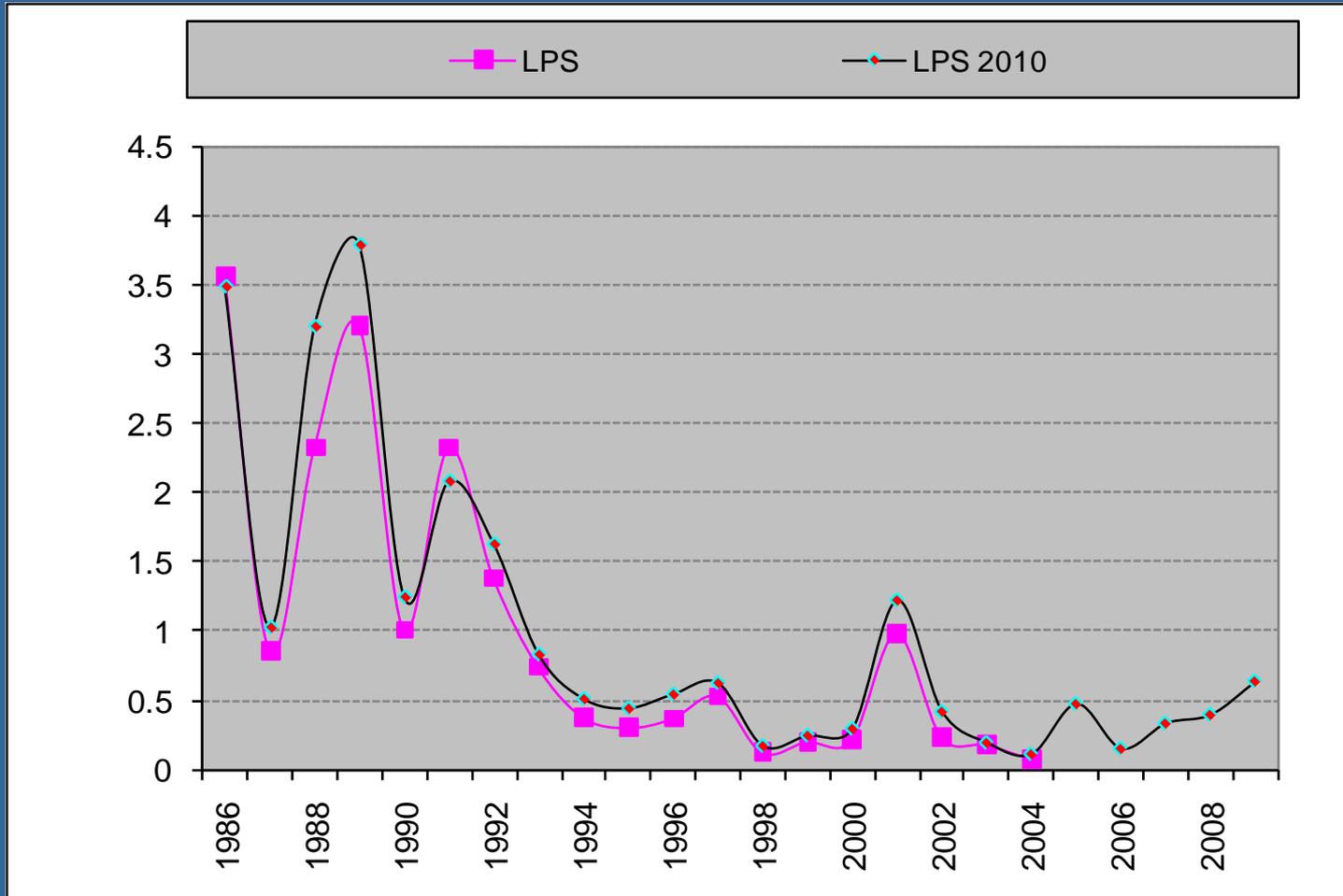


Rebuilding target
(year 2051)

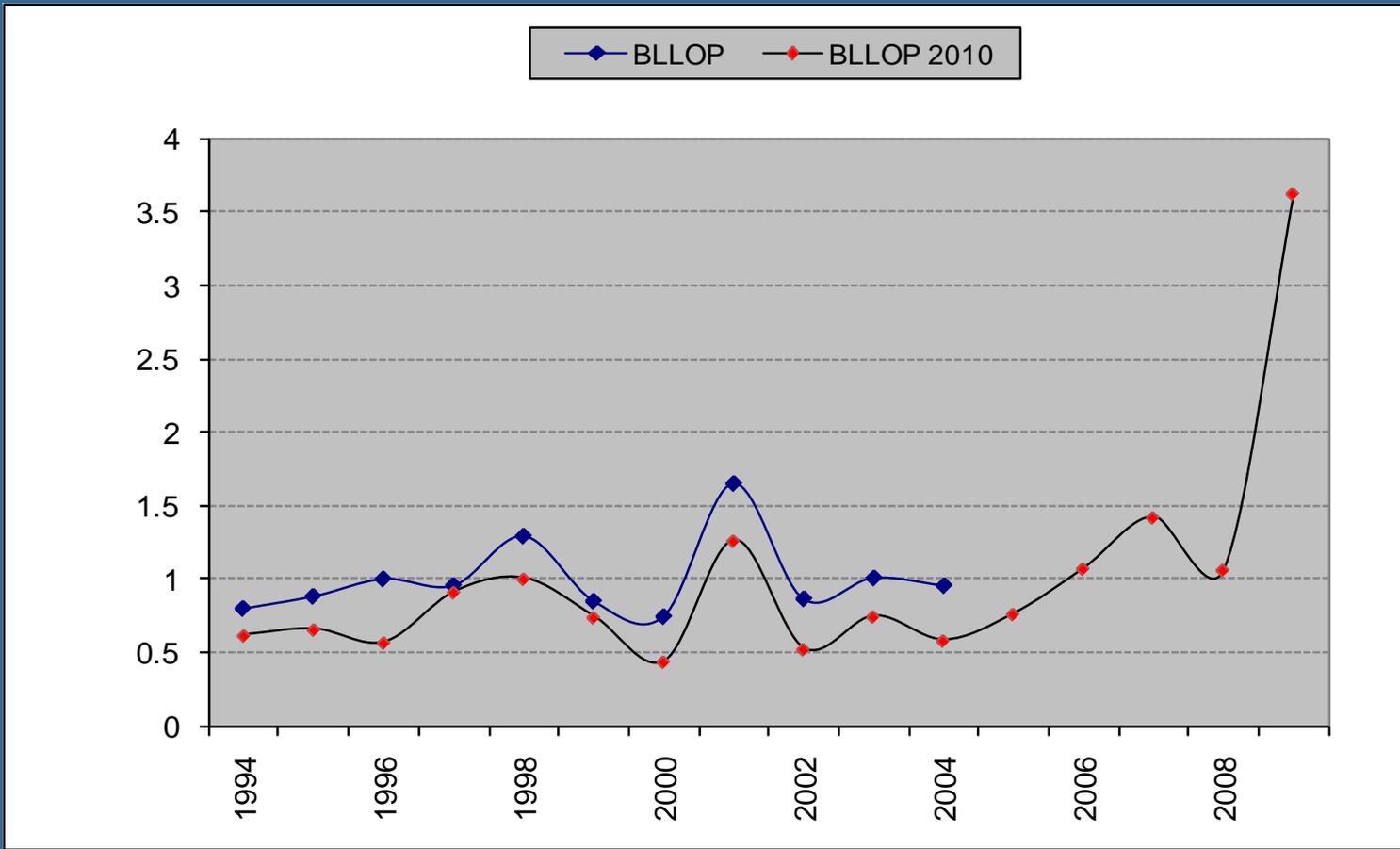
Old rebuilding target
(year 2070)

Additional

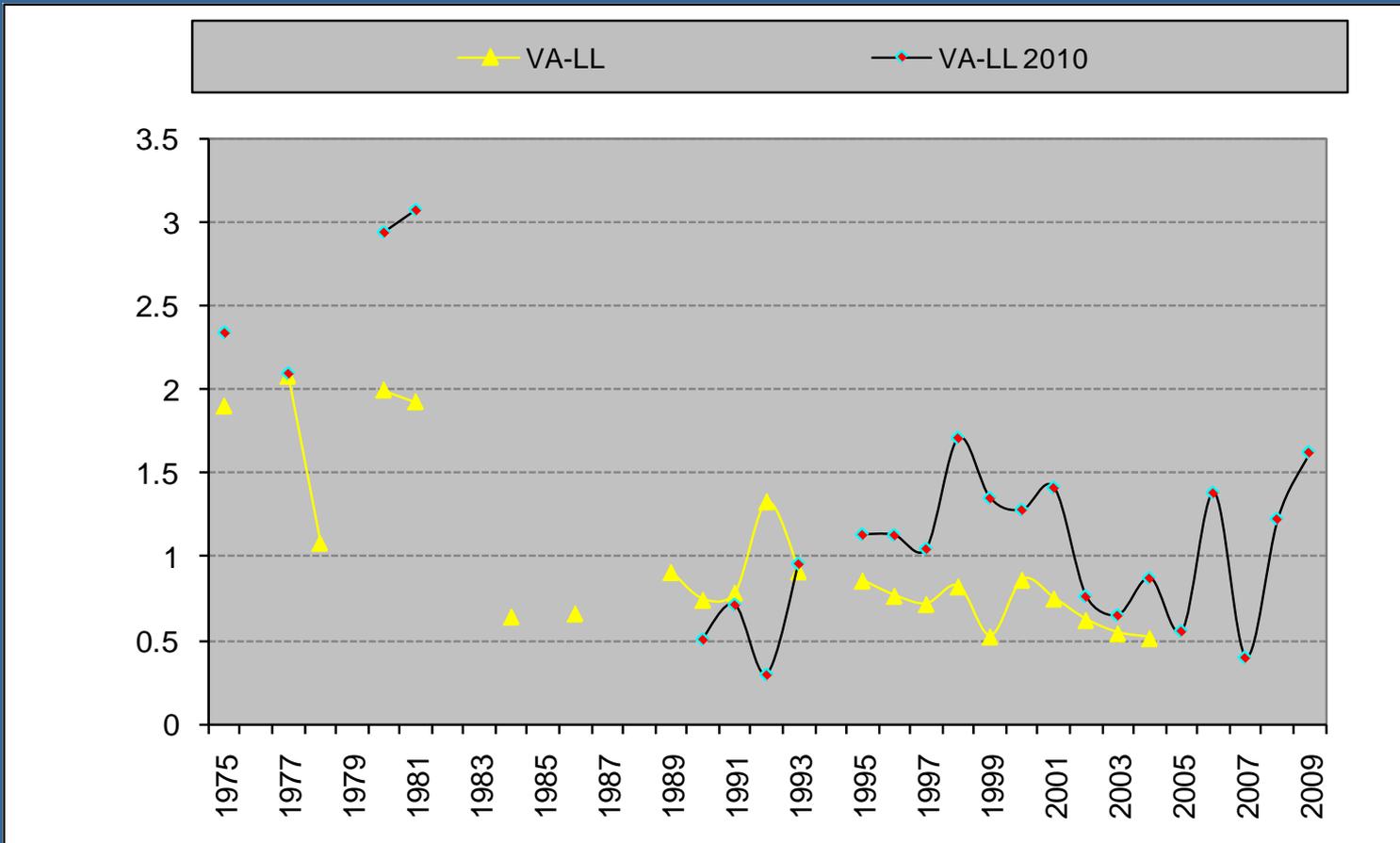
LPS



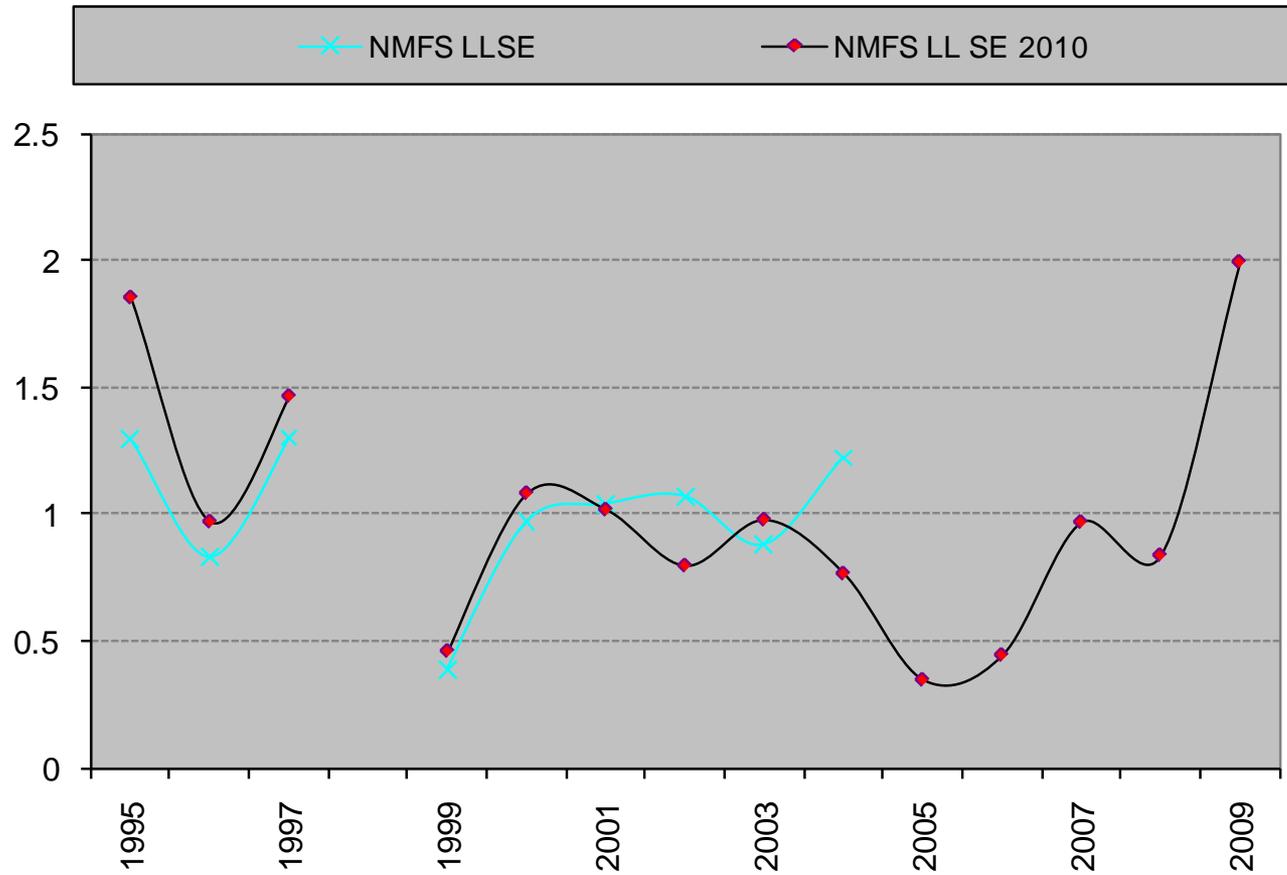
BLLOP



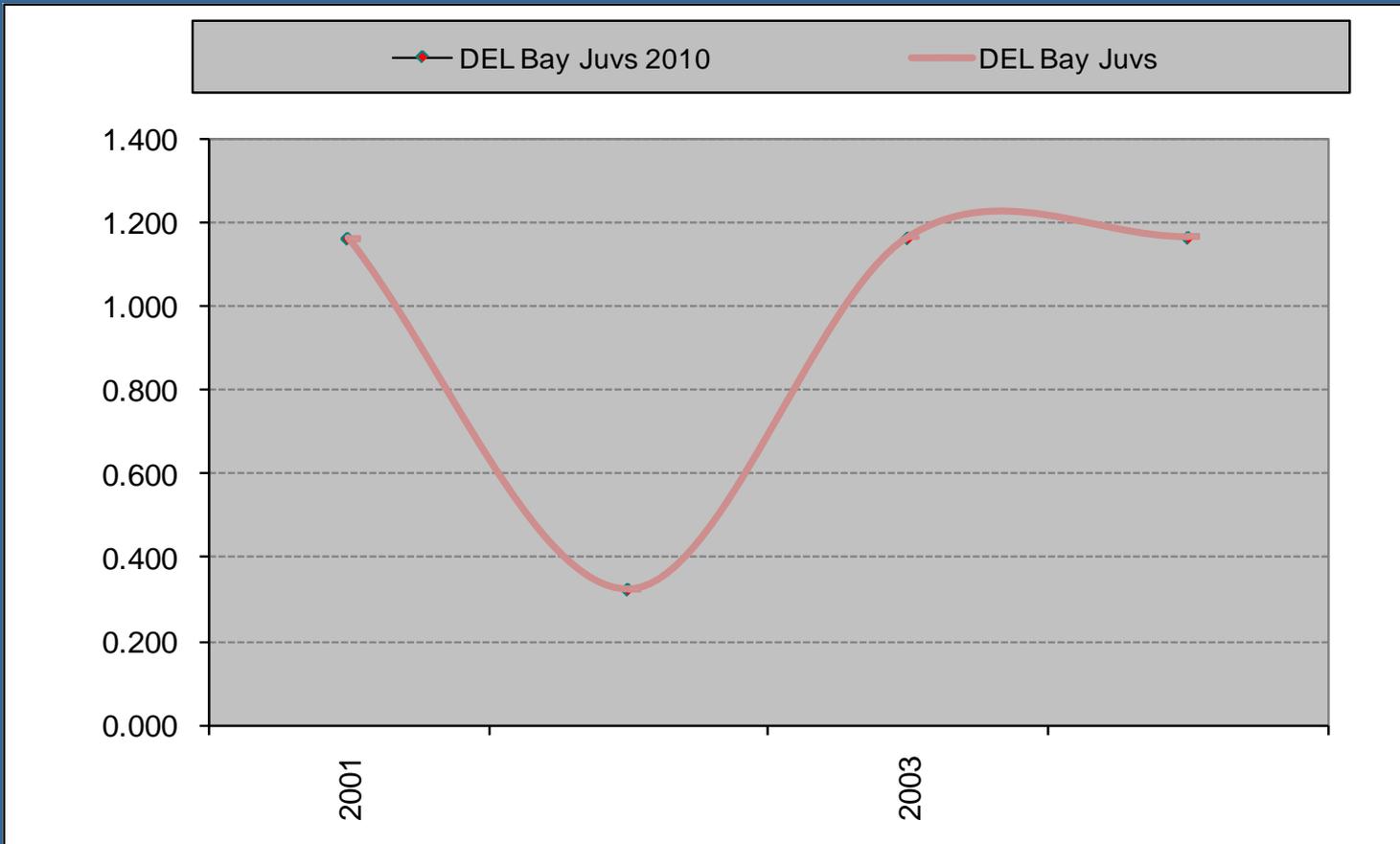
VA-LL



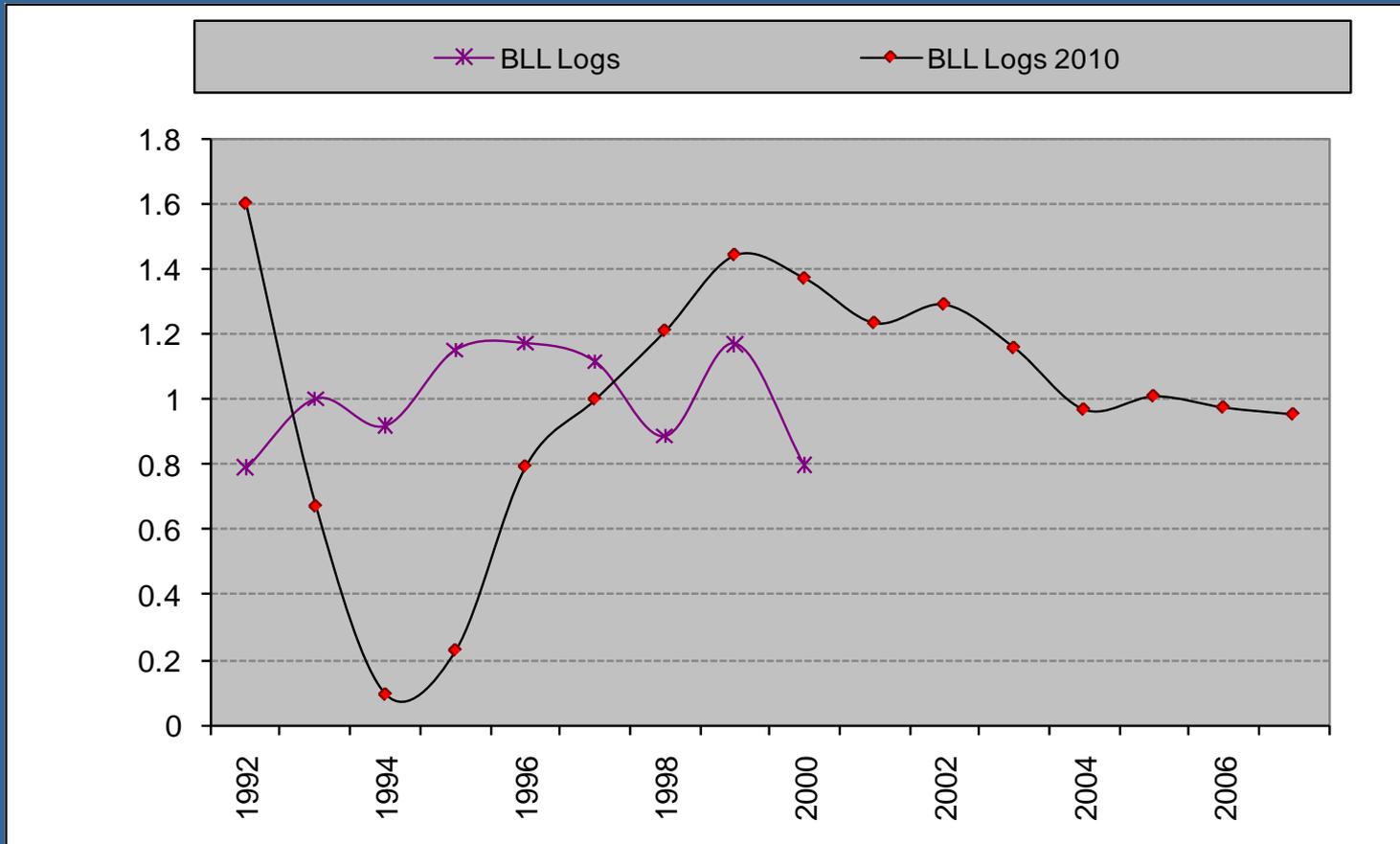
NMFS-LL-SE



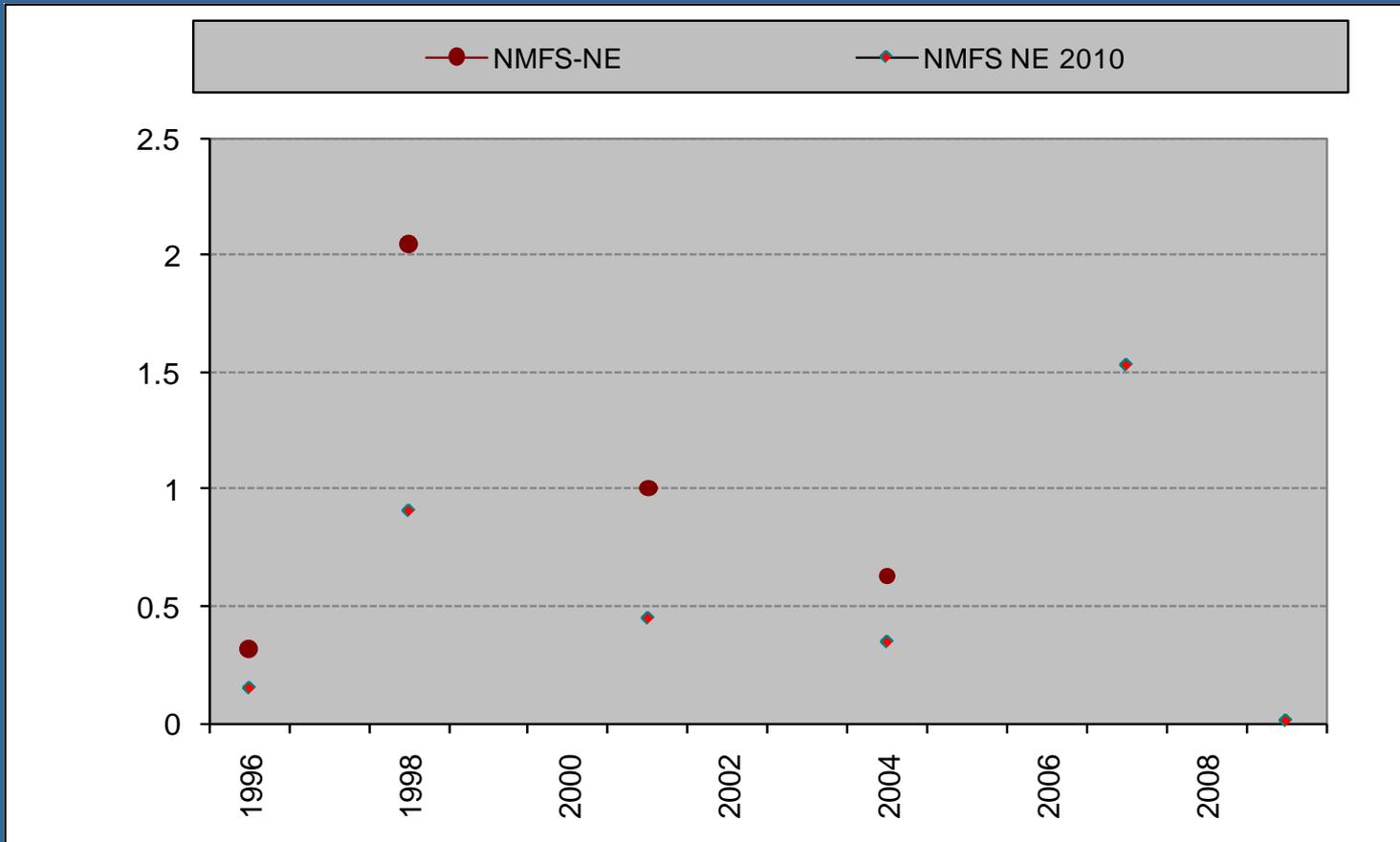
DEL-BAY-Juveniles



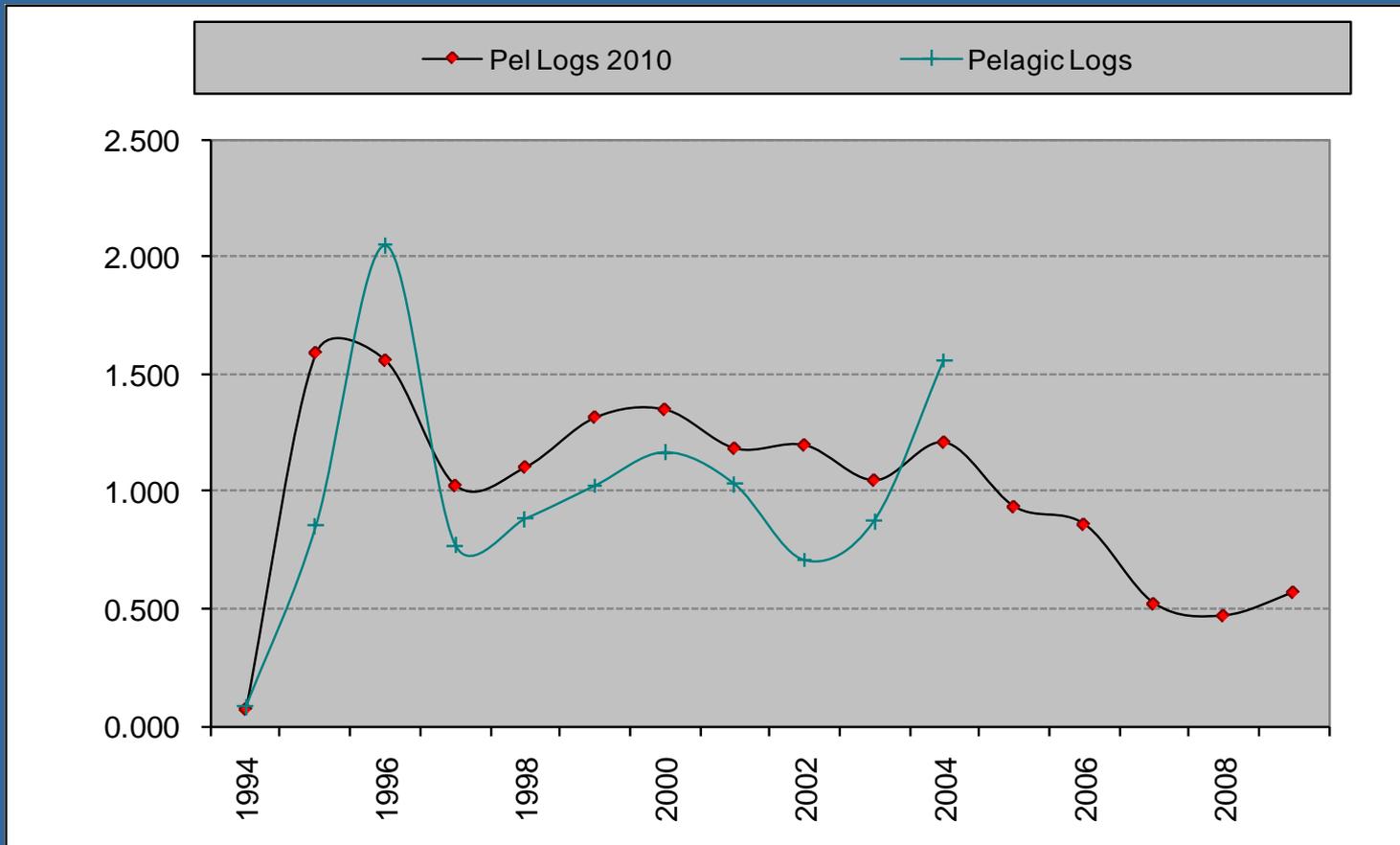
BLL-Logs



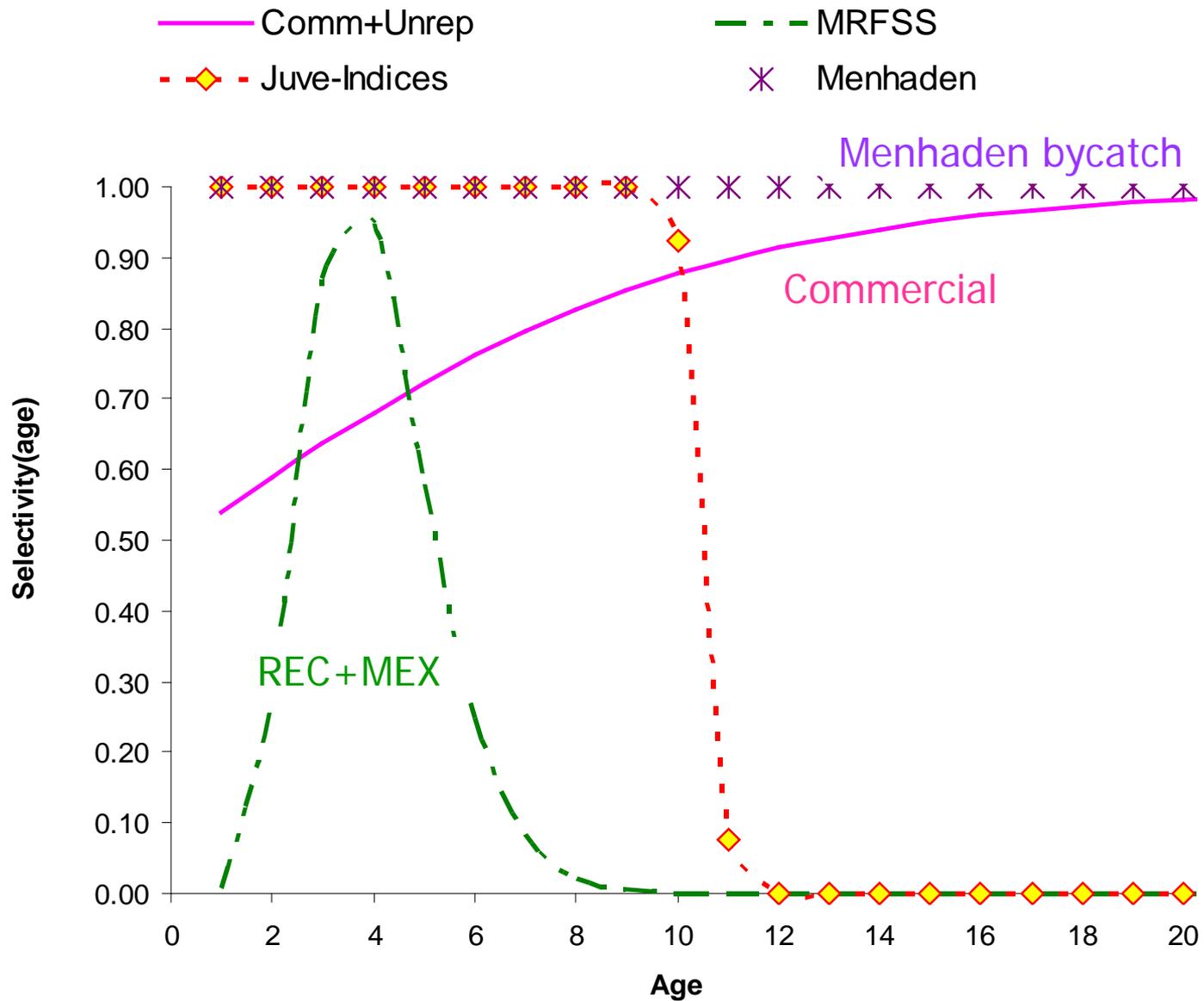
NMFS-NE



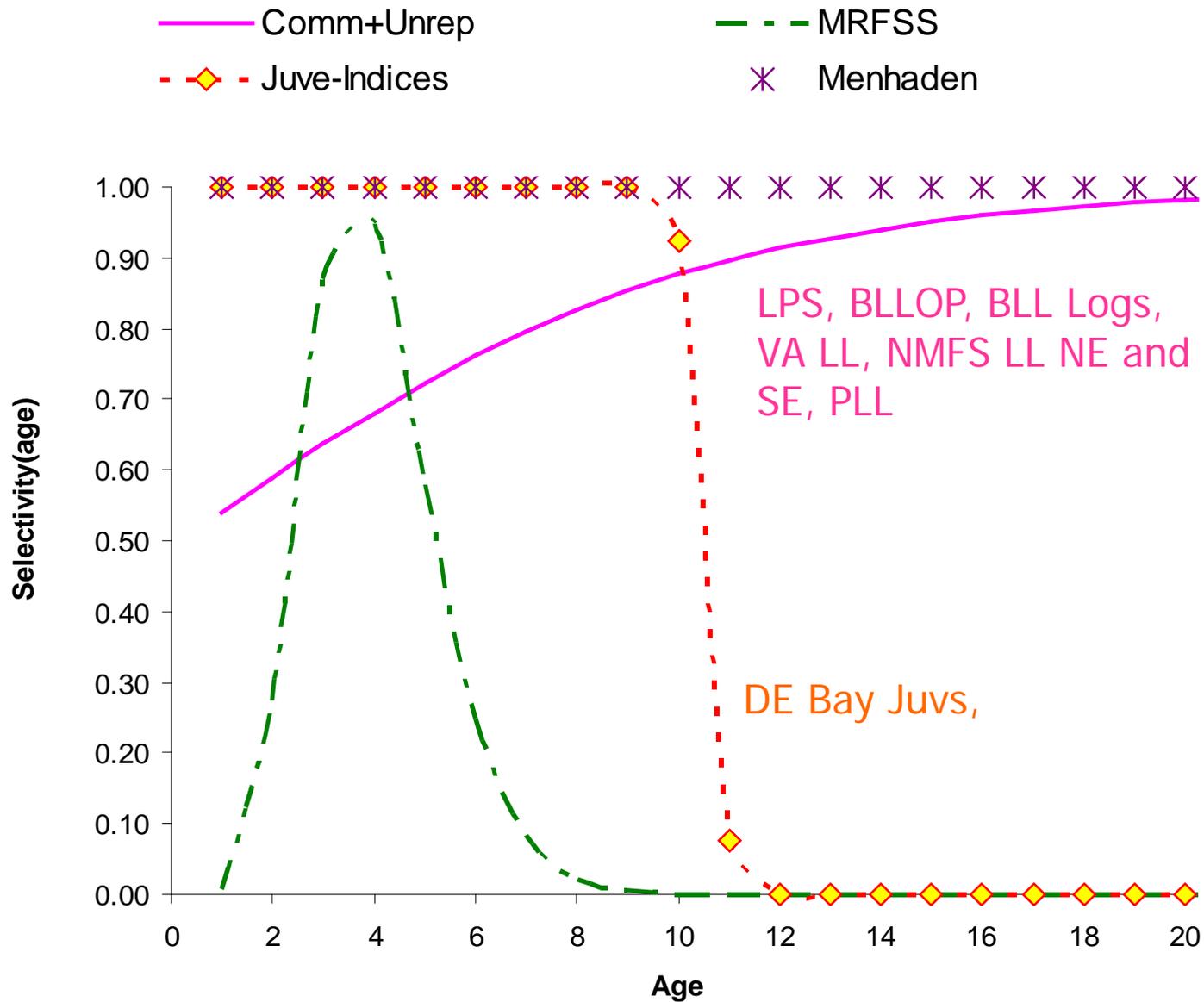
PLL



Selectivity - Catch

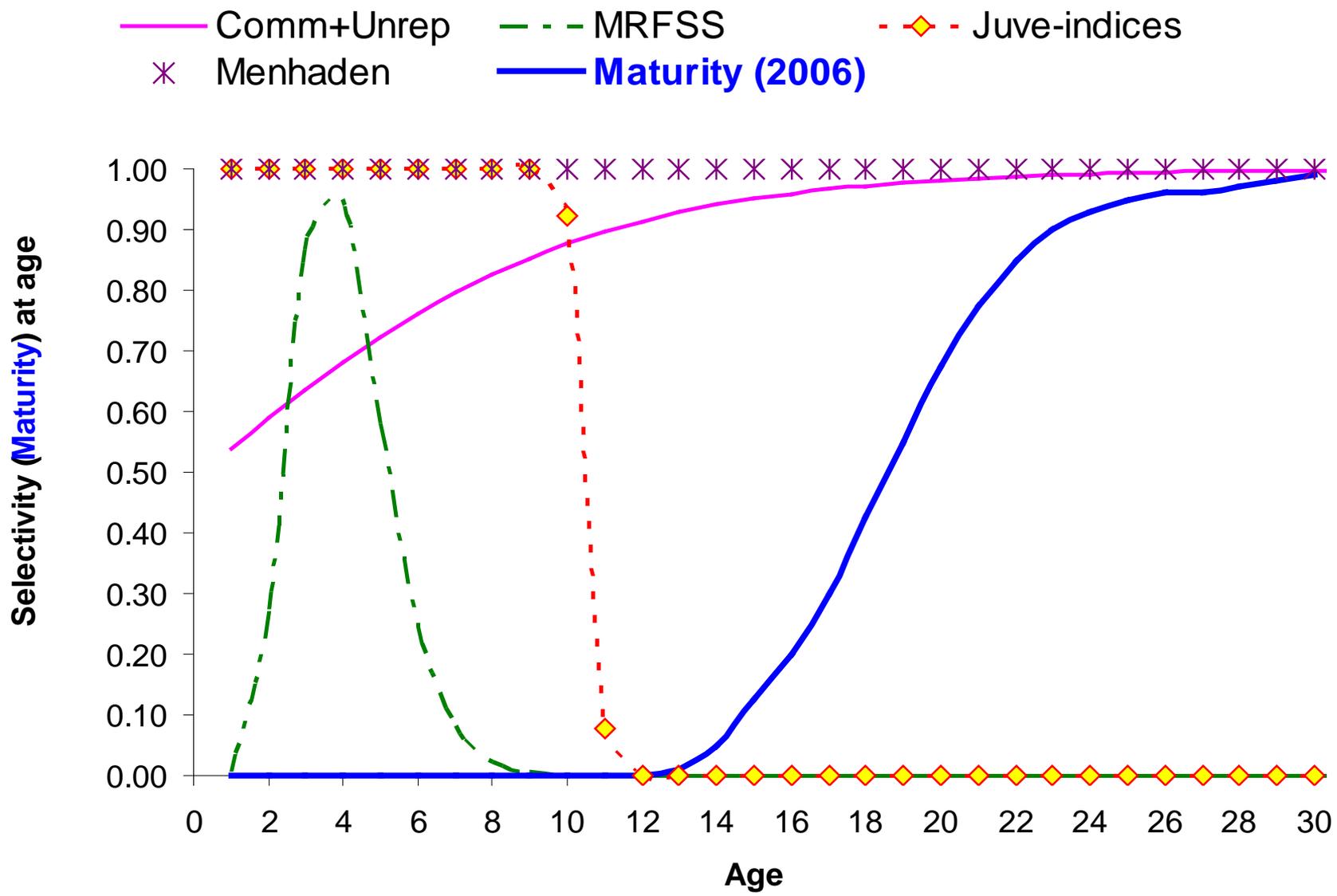


Selectivity - Indices



Biological Inputs

- Pup-production: 8.4 (biennial)
- Natural Mortality: 0.23 \rightarrow 0.07
- Pup-Survival: mode 0.75
- Maturity: \sim 50% age 19.5;
 \sim 100% age 30



Steepness – Max. Repro Rate (α)

- $\alpha = \text{pup.survival} \times \text{virgin.spawners.per.recruit}$

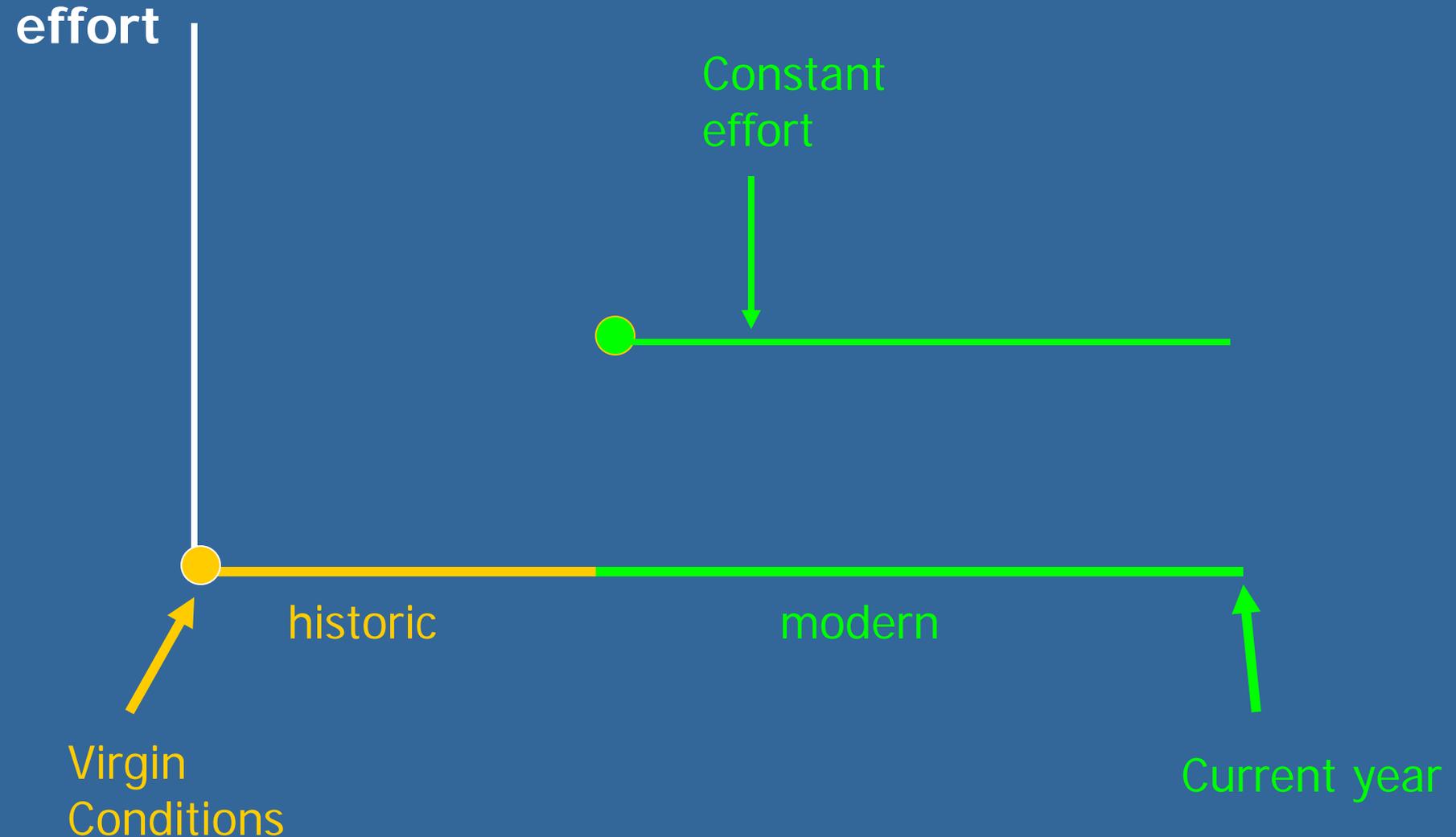
$$\alpha = \text{pup.survival} \times \varphi_0 = \sum_{age} fec_{age} \cdot mat_{age} \prod_{j=1}^{age-1} e^{-M_j}$$

- Steepness = $\alpha / (\alpha + 4)$

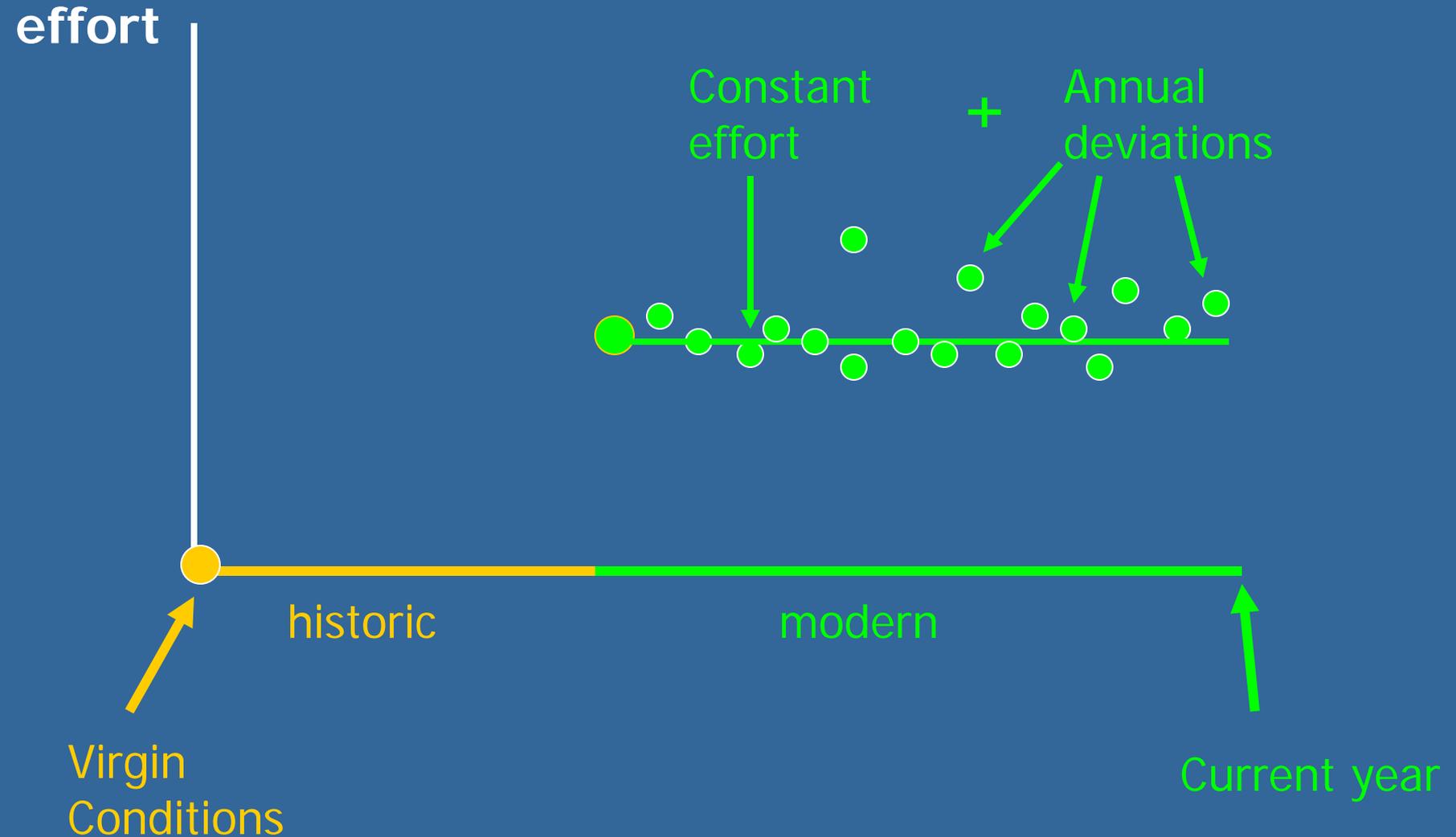
2. Model Description

- Time series split into **historic** and **modern** period
- **Historic period** begins in year when virgin conditions can be assumed; spans years where data are very sparse
- **Modern period** spans recent years, when data are presumed to be more abundant

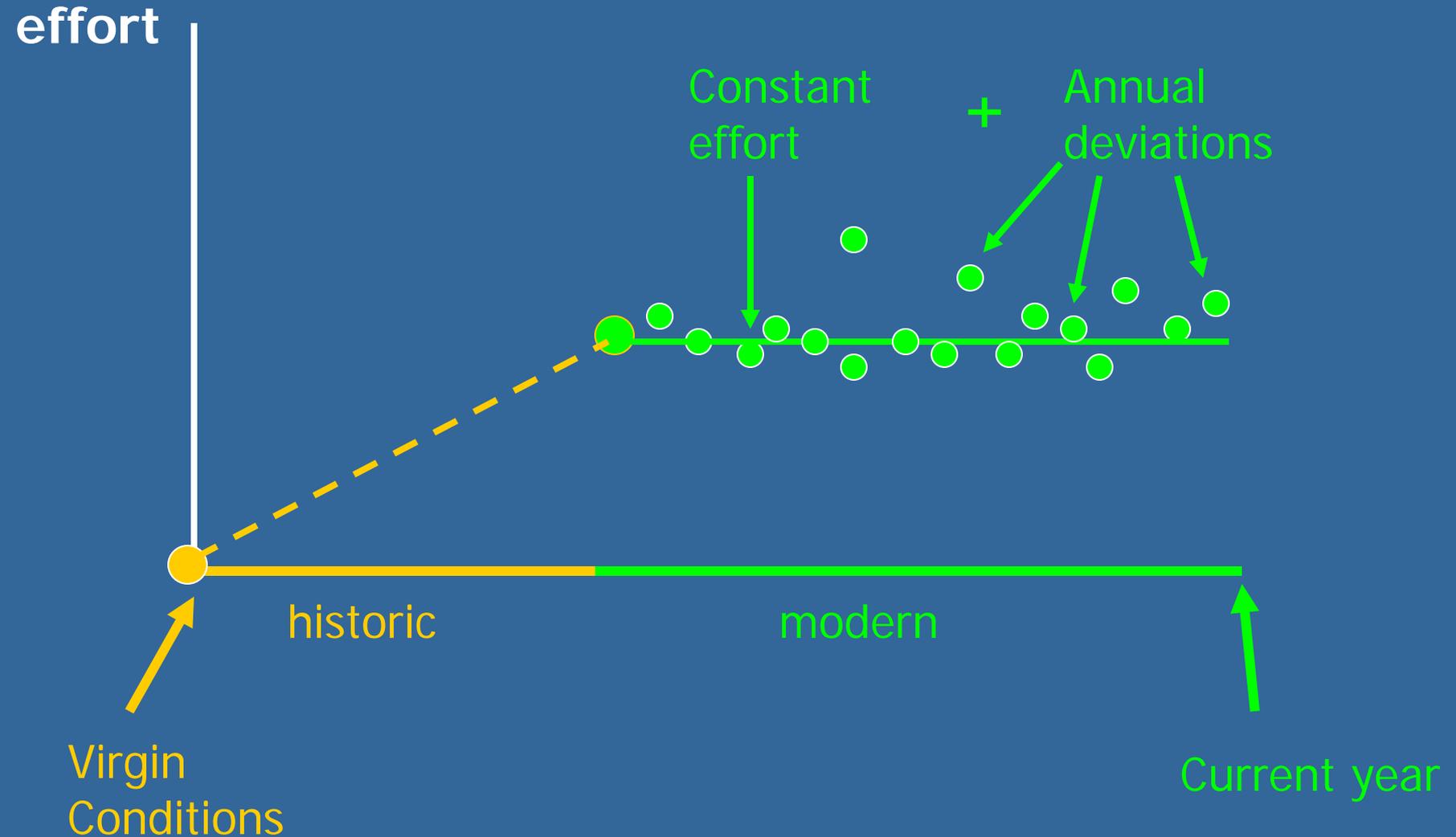
2. Model Description



2. Model Description



2. Model Description



7. Retrospective analyses

