SCALE Model (Statistical Catch At LEngth)

TOR 1 Modeling Approaches

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NOAA FISHERIES
Northeast Fisheries Science Center

Complex

S
S

Simple

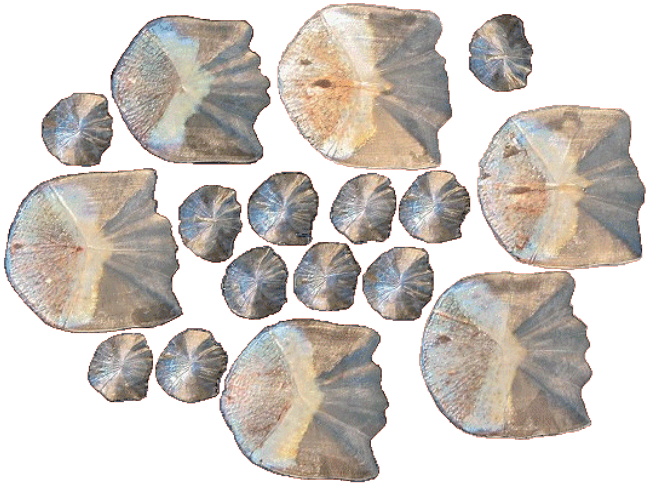
VPA (Data Rich)

ASAP, CASA

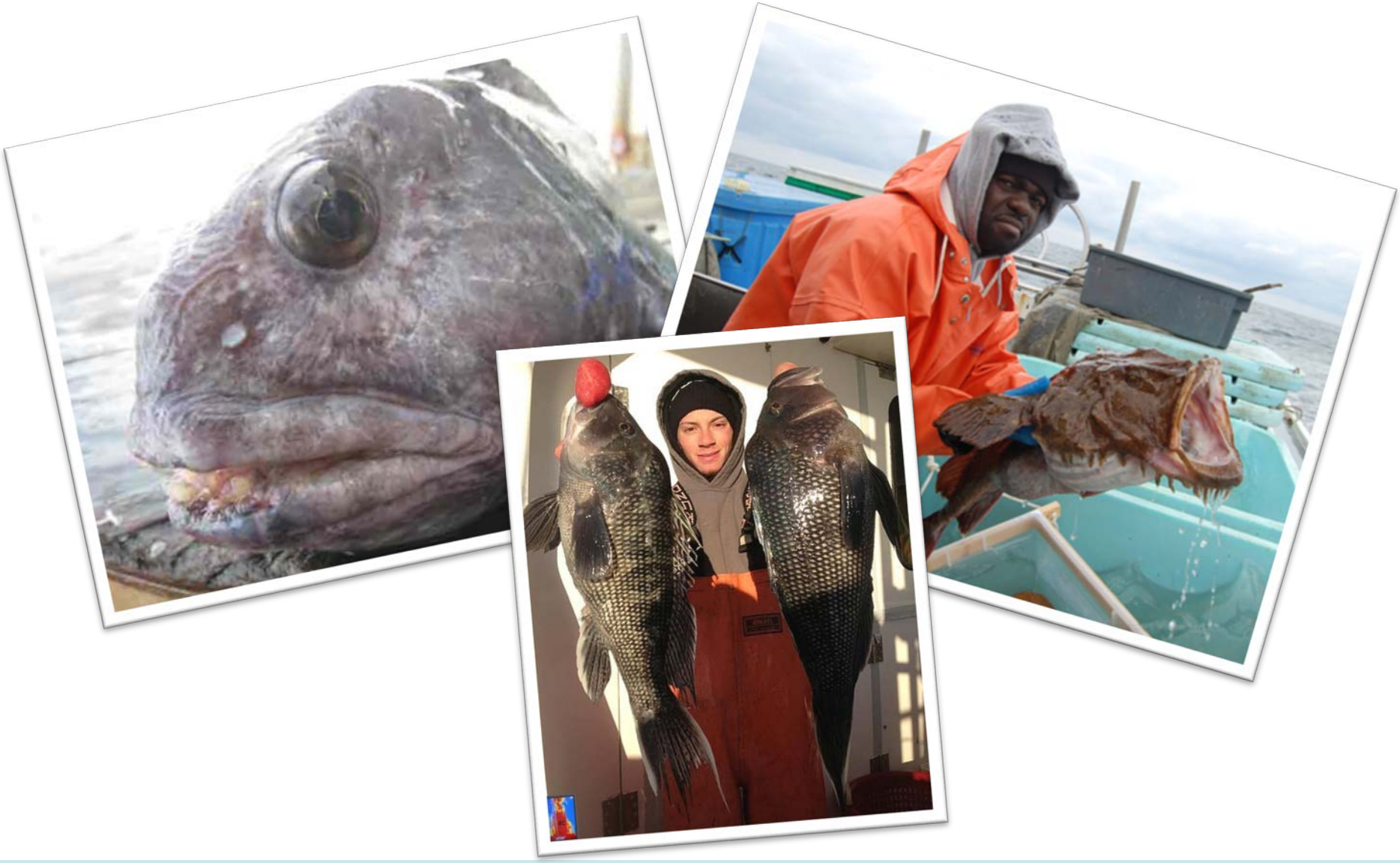
SCALE

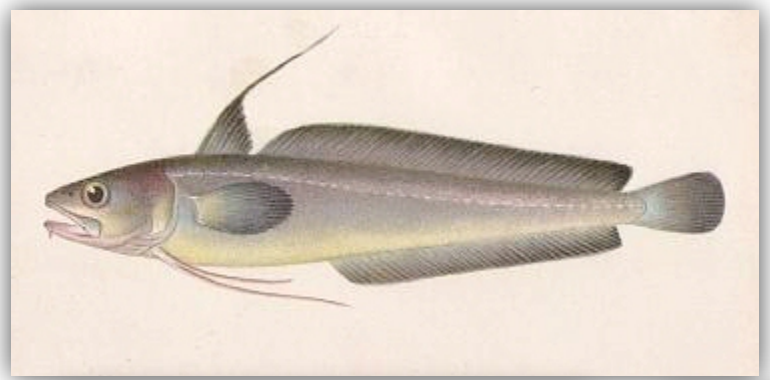
CSA

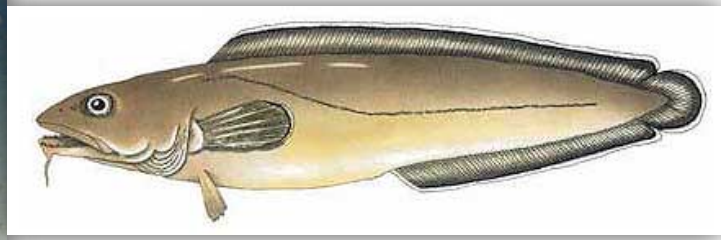
ASPIC, AIM (Data Poor)



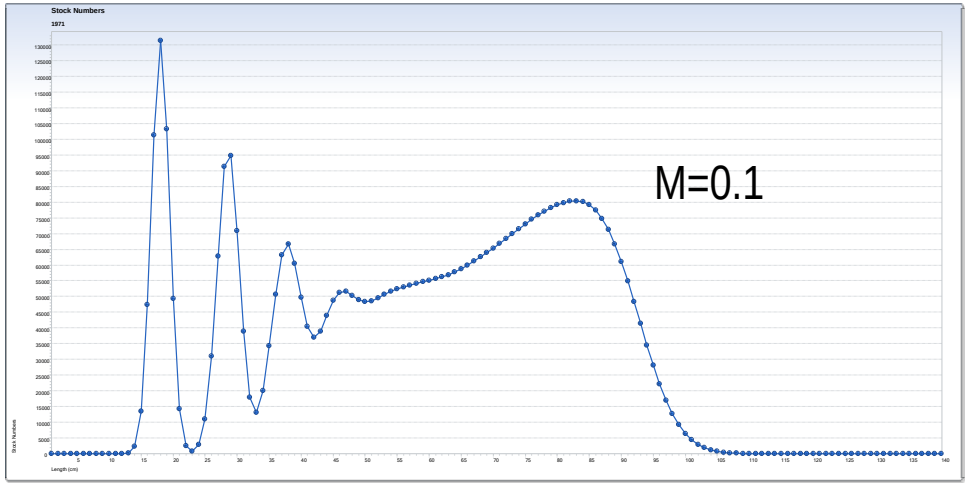
SCALE Stock Assessment

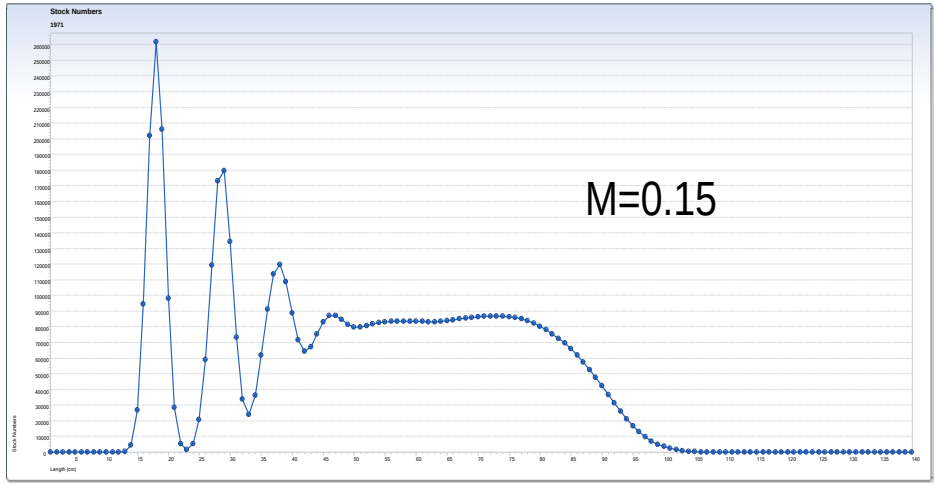


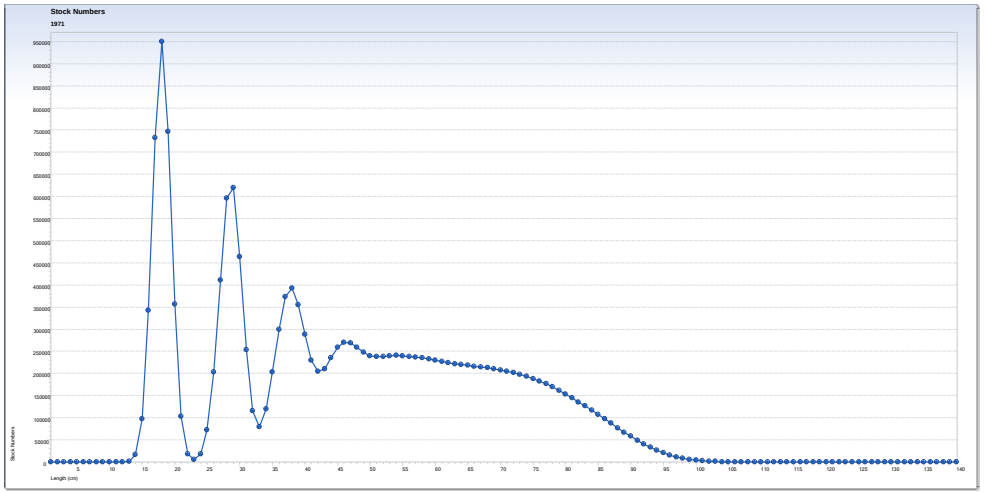




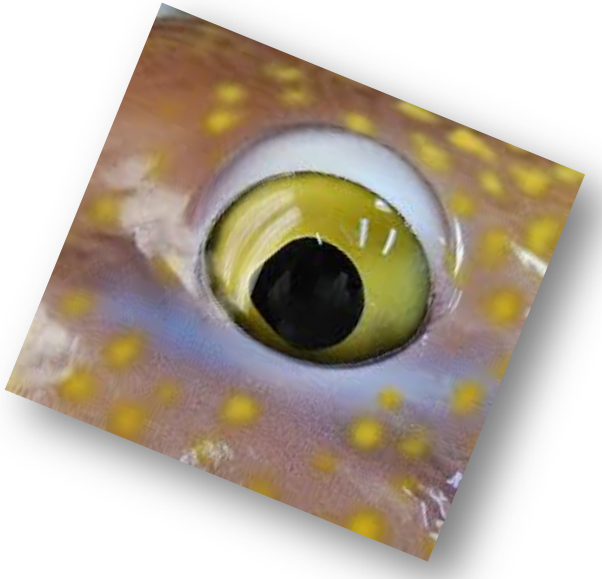
SCALE stock assessments model attempts







M=0.2



Equilibrium population numbers at length distributions

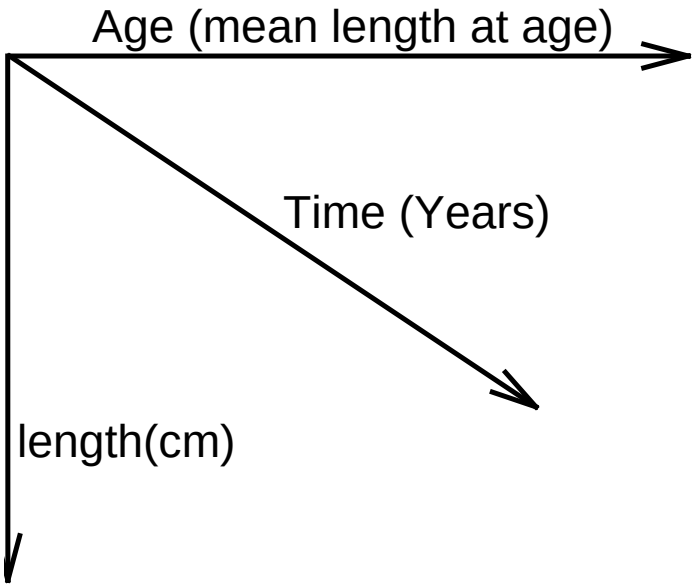
Just SCALE it…

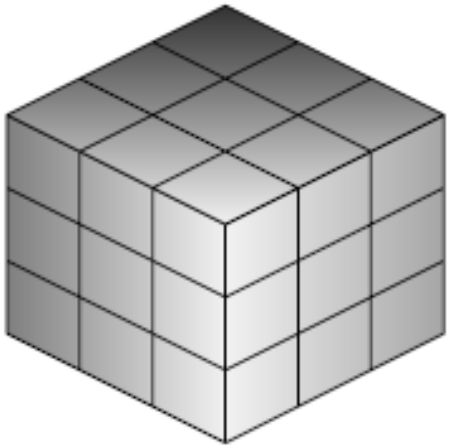
SCALE is a forward projecting age-based model designed for data poor-ish situations. The model does not rely on production ageing but does utilize information on the overall growth of the stock.

The same basic fish math is used within SCALE

So how is SCALE different from a typical forward projecting age-based model?

ADMB (3 dimensional arrays)

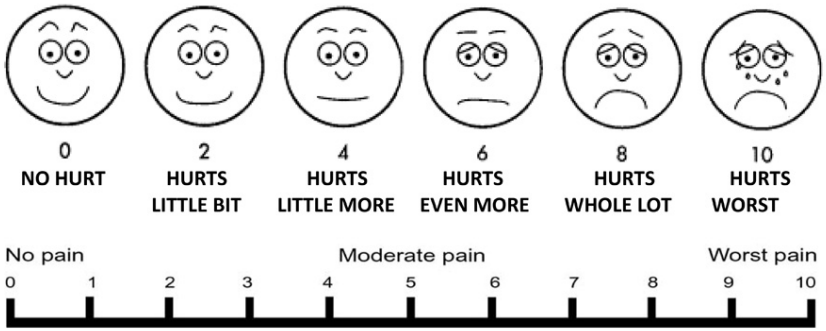




1) Growth is modeled with static mean lengths at age with normal variation.
2) Selectivity is modeled on length (not age).
3) Designed to fit length information based on flat topped assumptions.

SCALE

Forward projecting age-based model tuned to….



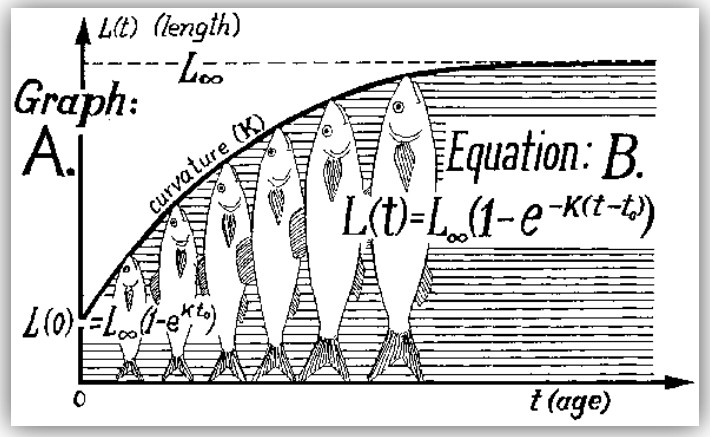
Total catch (metric tons)

Catch length frequency

Larger fish in the survey at the point where growth slows and there are many ages at a particular length (total in number and the length frequency)

Young age mode (first mode in survey length frequency through length slicing)

Model Assumptions



- Fish grow in a single time step each year.
- Fish growth follows the input mean length at age with input normal variation.
- Fish length at age is unaffected by the intensity of fishing or selectivity at an earlier age.
- Flat top selectivity with catch (logistic @ length) and surveys.

Input Variables

- M
- Mean lengths at age (von Bertalanffy, age-length key)
- Variation around the mean length at age
- Length-weight parameters
- Initial guess for parameters

Recruitment

- Recruitment in year 1 produces the initial population and age 2 in year 2.
- Recruitment in year 1 can be thought of as the average long term recruitment (population scalar).
- Recruitment in each year after year 1 is modeled as variation from year one (Vrec).
- Penalty or Weight on variation in recruitment.

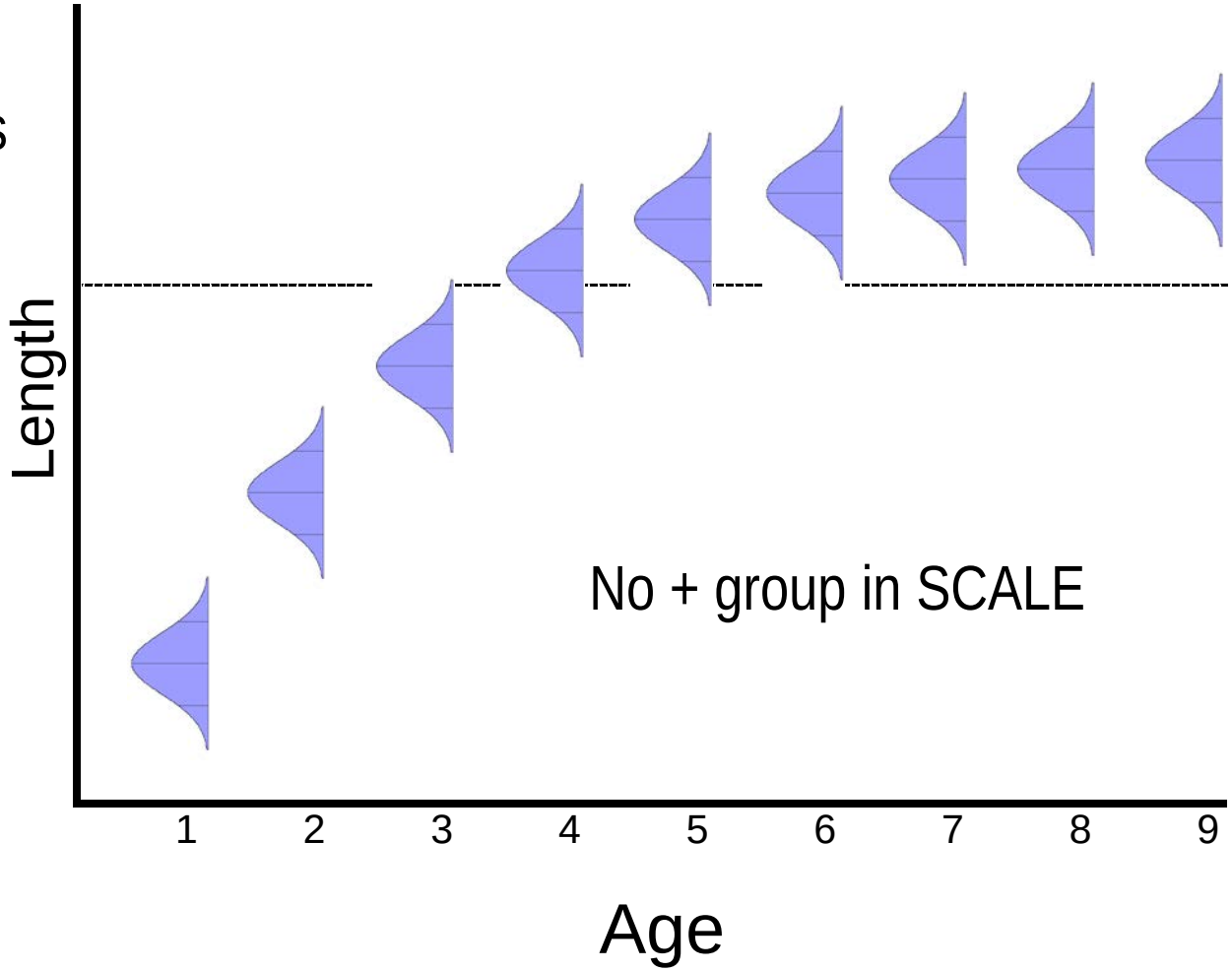
Estimated Parameters

- F used to estimate initial population (Fstart)
- F for each year
- Recruitment for each year
- Q for each index
- 2 parameters for each selectivity block

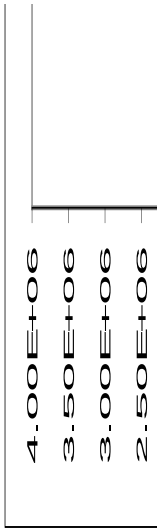
The way Joe normal fish grows

Catch &
40+ indices

Indices
at
age



Population

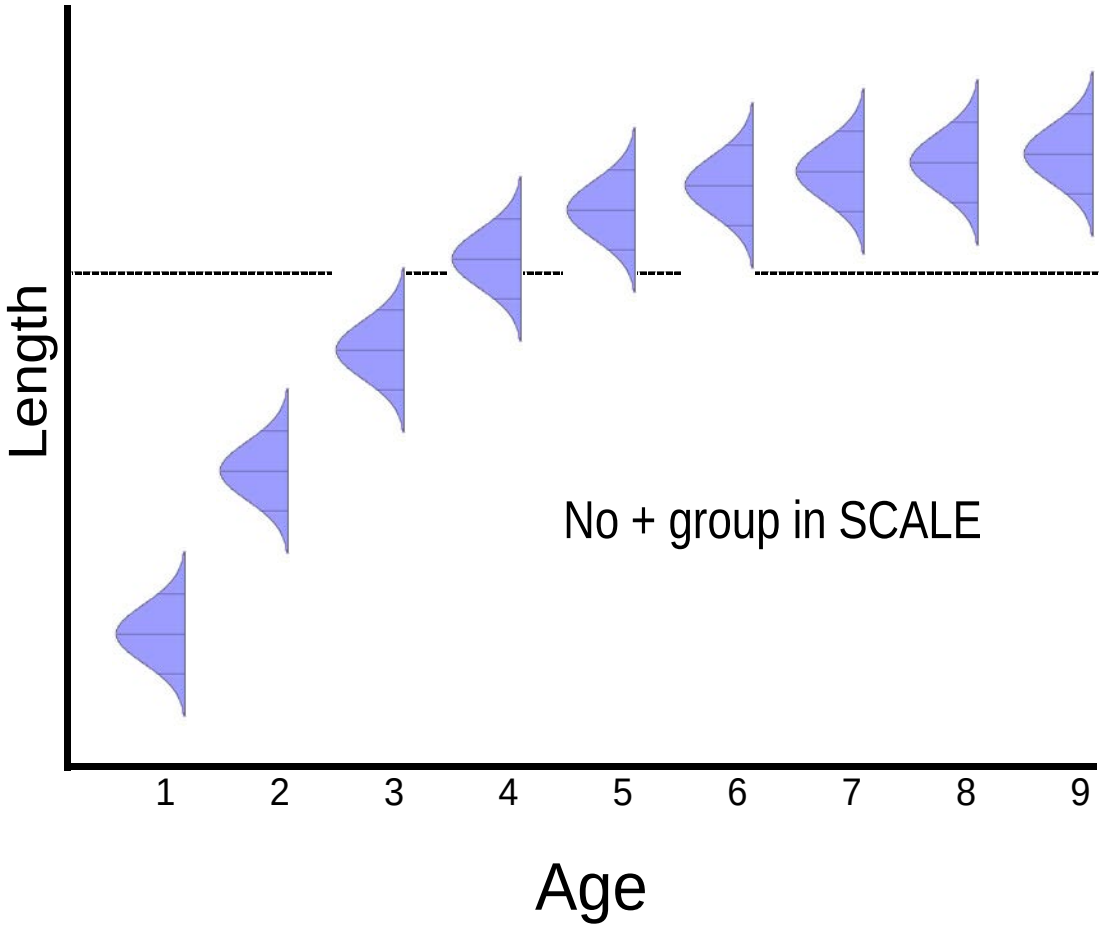


Population

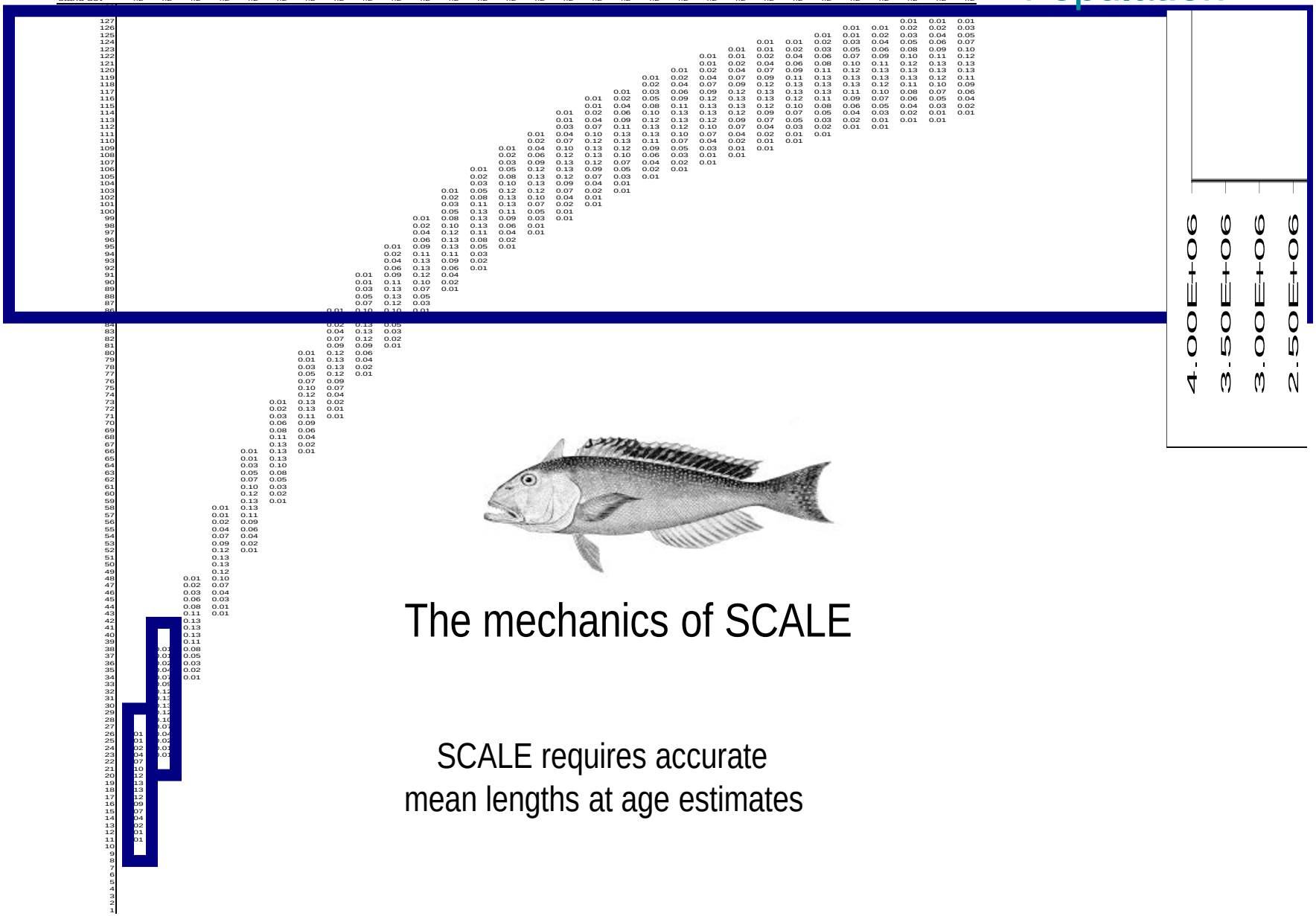
Selectivity

Catch
Length
Frequency

The way Joe normal fish grows



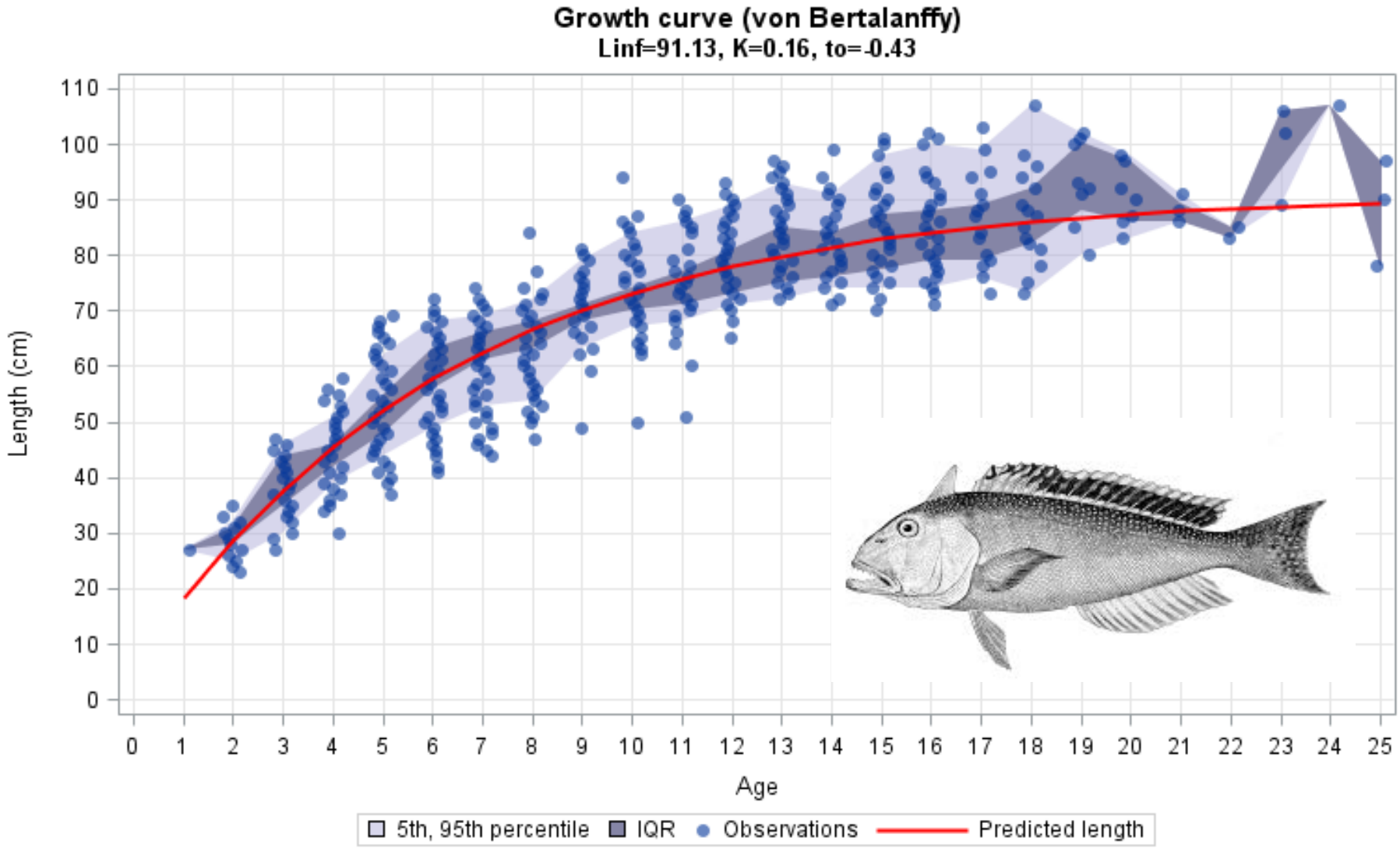
Population

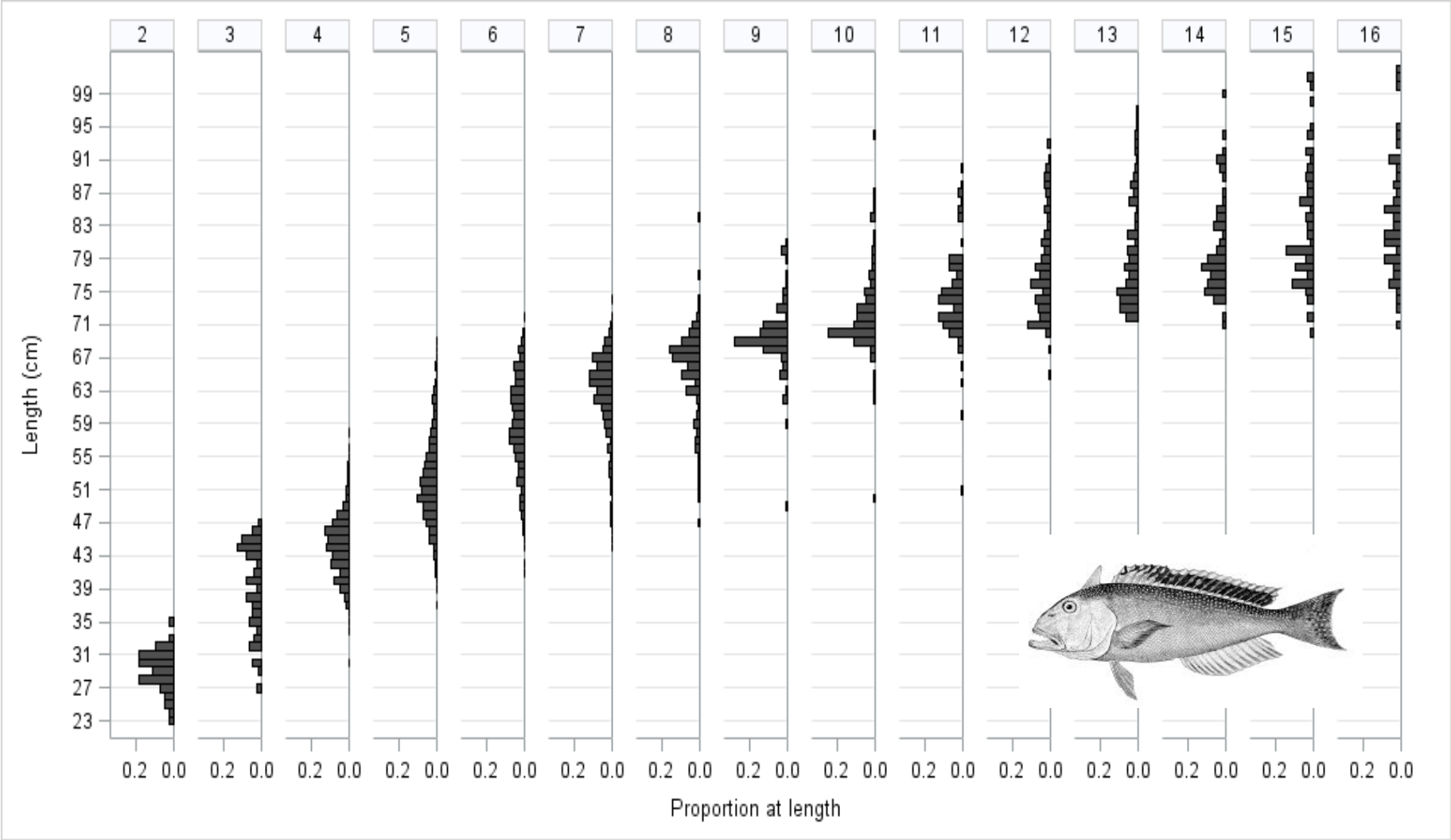


Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
mean len	18.5	30.5	41.0	50.4	58.7	66.1	72.7	78.5	83.6	88.2	92.2	95.8	99.0	101.8	104.3	106.6	108.5	110.3	111.8	113.2	114.4	115.5	116.5	117.3	118.1	118.7	119.3	119.9	120.3	120.8
stand dev	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
127																												0.01	0.01	0.01
126																										0.01	0.01	0.02	0.02	0.03
125																									0.01	0.01	0.02	0.03	0.04	0.05
124																							0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07
123																						0.01	0.01	0.02	0.03	0.05	0.06	0.08	0.09	0.10
122																					0.01	0.01	0.02	0.04	0.06	0.07	0.09	0.10	0.11	0.12
121																					0.01	0.02	0.04	0.06	0.08	0.10	0.11	0.12	0.13	0.13
120																				0.01	0.02	0.04	0.07	0.09	0.11	0.12	0.13	0.13	0.13	0.13
119																			0.01	0.02	0.04	0.07	0.09	0.11	0.13	0.13	0.13	0.13	0.12	0.11
118																			0.02	0.04	0.07	0.09	0.12	0.13	0.13	0.13	0.12	0.11	0.10	0.09
117																		0.01	0.03	0.06	0.09	0.12	0.13	0.13	0.13	0.11	0.10	0.08	0.07	0.06
116																	0.01	0.02	0.05	0.09	0.12	0.13	0.13	0.12	0.11	0.09	0.07	0.06	0.05	0.04
115																	0.01	0.04	0.08	0.11	0.13	0.13	0.12	0.10	0.08	0.06	0.05	0.04	0.03	0.02
114																0.01	0.02	0.06	0.10	0.13	0.13	0.12	0.09	0.07	0.05	0.04	0.03	0.02	0.01	0.01
113																0.01	0.04	0.09	0.12	0.13	0.12	0.09	0.07	0.05	0.03	0.02	0.01	0.01	0.01	
112																0.03	0.07	0.11	0.13	0.12	0.10	0.07	0.04	0.03	0.02	0.01	0.01			
111															0.01	0.04	0.10	0.13	0.13	0.10	0.07	0.04	0.02	0.01	0.01					
110															0.02	0.07	0.12	0.13	0.11	0.07	0.04	0.02	0.01	0.01						
109														0.01	0.04	0.10	0.13	0.12	0.09	0.05	0.03	0.01	0.01							
108														0.02	0.06	0.12	0.13	0.10	0.06	0.03	0.01	0.01								
107														0.03	0.09	0.13	0.12	0.07	0.04	0.02	0.01									
106													0.01	0.05	0.12	0.13	0.09	0.05	0.02	0.01										
105													0.02	0.08	0.13	0.12	0.07	0.03	0.01											
104													0.03	0.10	0.13	0.09	0.04	0.01												
103												0.01	0.05	0.12	0.12	0.07	0.02	0.01												
102												0.02	0.08	0.13	0.10	0.04	0.01													
101												0.03	0.11	0.13	0.07	0.02	0.01													
100												0.05	0.13	0.11	0.05	0.01														
99											0.01	0.08	0.13	0.09	0.03	0.01														
98											0.02	0.10	0.13	0.06	0.01															
97											0.04	0.12	0.11	0.04	0.01															
96											0.06	0.13	0.08	0.02																
95										0.01	0.09	0.13	0.05	0.01																
94										0.02	0.11	0.11	0.03																	
93										0.04	0.13	0.09	0.02																	
92										0.06	0.13	0.06	0.01																	
91									0.01	0.09	0.12	0.04																		
90									0.01	0.11	0.10	0.02																		
89									0.03	0.13	0.07	0.01																		
88									0.05	0.13	0.05																			
87									0.07	0.12	0.03																			
86								0.01	0.10	0.10	0.01																			
85								0.02	0.13	0.05																				
84								0.04	0.13	0.03																				
83								0.07	0.12	0.02																				
82								0.09	0.09	0.01																				
81							0.01	0.12	0.06																					
80							0.01	0.13	0.04																					
79							0.03	0.13	0.02																					
78							0.05	0.12	0.01																					
77							0.07	0.09																						
76							0.10	0.07																						
75							0.12	0.04																						
74						0.01	0.13	0.02																						
73						0.02	0.13	0.01																						
72						0.03	0.11	0.01																						
71						0.06	0.09																							
70						0.08	0.06																							
69						0.11	0.04																							
68						0.13	0.02																							
67						0.13	0.01																							
66					0.01	0.13																								
65					0.01	0.13																								
64					0.03	0.10																								
63					0.05	0.08																								
62					0.07	0.05																								
61					0.10	0.03																								
60					0.12	0.02																								
59					0.13	0.01																								
58				0.01	0.13																									
57				0.01	0.11																									
56				0.02	0.09																									
55				0.04	0.06																									
54				0.07	0.04																									
53				0.09	0.02																									
52				0.12	0.01																									
51				0.13																										
50				0.13																										
49				0.12																										
48			0.01	0.10																										
47			0.02	0.07																										
46			0.03	0.04																										
45			0.06	0.03																										
44			0.08	0.01																										
43			0.11	0.01																										
42			0.13																											
41			0.13																											
40			0.13																											
39			0.11																											
38		0.01	0.08																											
37		0.01	0.05																											
36		0.02	0.03																											
35		0.04	0.02																											
34		0.07	0.01																											
33		0.09																												
32		0.12																												
31		0.13																												
30		0.13																												
29		0.12																												
28		0.10																												
27		0.07																												
26	0.01	0.04																												
25	0.01	0.02																												
24	0.02	0.01																												
23	0.04	0.01																												
22	0.07																													
21	0.10																													
20	0.12																													
19	0.13																													
18	0.13																													
17	0.12																													
16	0.09																													
15	0.07																													
14	0.04																													
13	0.02																													
12	0.01																													
11	0.01																													
10																														
9																														
8																														
7																														
6																														
5																														
4																														
3																														
2																														
1																														

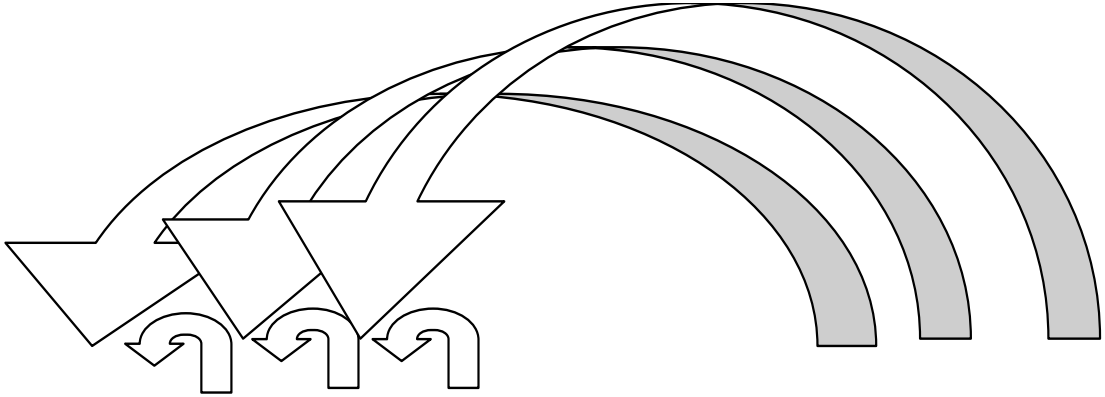
The mechanics of SCALE

SCALE requires accurate
mean lengths at age estimates


Growth curve (von Bertalanffy)
Linf=91.13, K=0.16, to=-0.43
Length (cm)
0
10
20
30
40
50
60
70
80
90
100
110
Age
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
5th, 95th percentile
IQR
Observations
Predicted length


2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Length (cm)
99
95
91
87
83
79
75
71
67
63
59
55
51
47
43
39
35
31
27
23
0.2 0.0
Proportion at length

SCALE



recruitment age 2 age 3 age n

len 1
len 2
len 3
len 4
len 5
len 6
len n

Initial Population, year 1

Equilibrium startup (Fstart)

age 1 age 2 age 3 age n

len 1
len 2
len 3
len 4
len 5
len 6
len n

Catch year 1

recruitment age 2 age 3 age n

len 1
len 2
len 3
len 4
len 5
len 6
len n

Population year 2

age 1 age 2 age 3 age n

len 1
len 2
len 3
len 4
len 5
len 6
len n

Catch year 2

recruitment age 2 age 3 age n

len 1
len 2
len 3
len 4
len 5
len 6
len n

Population year 3

age 1 age 2 age 3 age n

len 1
len 2
len 3
len 4
len 5
len 6
len n

Catch year 3

Option to model the population by Sex

	recruitment	age 2	age 3	age n
len 1				
len 2	**Females**			
len 3	Initial Population, year 1			
len 4				
len n				

+

	recruitment	age 2	age 3	age n
len 1				
len 2	**males**			
len 3	Initial Population, year 1			
len 4				
len n				

||

	recruitment	age 2	age 3	age n
len 1				
len 2				
len 3	Initial Population, year 1			
len 4				
len n				

	recruitment	age 2	age 3	age n
len 1				
len 2	**Females**			
len 3	Population year 2			
len 4				
len n				

+

	recruitment	age 2	age 3	age n
len 1				
len 2	**males**			
len 3	Population year 2			
len 4				
len n				

||

	recruitment	age 2	age 3	age n
len 1				
len 2				
len 3	Population year 2			
len 4				
len n				

Growth and M by sex

	recruitment	age 2	age 3	age n
len 1				
len 2	**Females**			
len 3	Population year n			
len 4				
len n				

+

	recruitment	age 2	age 3	age n
len 1				
len 2	**males**			
len 3	Population year n			
len 4				
len n				

||

	recruitment	age 2	age 3	age n
len 1				
len 2				
len 3	Population year n			
len 4				
len n				

Wolffish SCALE Example

Wolffish growth from Nelson & Ross 1992

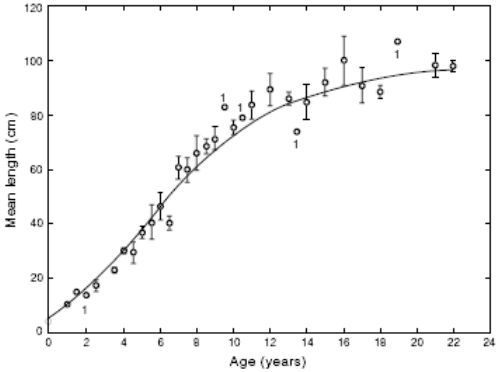


Fig. 6. Observed mean and predicted lengths-at-age of *Anarhichas lupus* from the Gulf of Maine-Georges Bank region. The predicted curve was fitted using a Gompertz function. The symbol "1" above or below a hollow dot represents the sample size for that age. Standard error bars are shown.

std	3	3	3.5	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
len/age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
122																										1	1	1	1	1
121																								1	1	1	2	2	2	2
120																						1	1	2	2	3	3	4	4	4
119																					1	1	2	4	5	6	7	8	8	8
118																				1	2	3	5	7	9	11	13	14	14	15
117																			1	2	4	7	10	14	18	20	23	24	25	24
116																		1	2	4	8	13	20	26	31	35	38	39	39	39
115																		1	4	9	16	25	35	44	52	57	60	61	60	58
114																	1	3	8	17	30	45	60	73	82	88	90	90	87	82
113																	2	6	17	33	54	76	97	113	123	128	128	125	118	110
112																1	4	14	32	59	90	122	148	165	175	177	172	164	152	140
111																2	9	27	58	100	144	184	213	229	235	230	219	204	186	168
110															1	5	19	50	100	160	217	263	291	301	297	283	263	239	215	190
109															2	11	37	89	163	242	310	355	375	374	357	330	299	266	234	204
108															4	22	68	149	251	347	418	454	458	439	405	364	321	280	242	208
107														1	9	42	119	237	365	471	533	549	529	488	435	380	327	279	236	200
106														3	20	78	197	354	504	604	643	628	579	512	442	375	314	262	218	182
105														6	39	137	307	503	657	734	734	680	598	509	424	350	286	233	191	156
104													1	13	74	226	454	674	811	843	792	696	585	479	386	309	246	197	158	127
103													3	28	132	354	634	855	947	916	809	674	541	426	332	258	200	157	123	98
102													6	54	222	523	838	1,026	1,046	941	782	617	474	358	270	204	154	118	91	71
101												1	14	101	354	732	1,048	1,165	1,092	915	714	535	392	285	208	152	113	84	64	49
100												2	29	177	533	969	1,240	1,251	1,079	842	618	439	307	215	151	107	78	57	42	32
99												4	57	294	761	1,213	1,388	1,271	1,009	732	505	340	228	153	104	72	51	36	26	20
98												9	106	462	1,028	1,437	1,469	1,222	892	603	391	250	159	103	68	45	31	22	16	11
97											1	20	188	687	1,312	1,611	1,471	1,111	746	469	286	173	106	66	42	27	18	12	9	6
96											1	41	315	965	1,585	1,707	1,394	955	590	345	198	114	66	40	24	15	10	7	5	3
95											4	81	499	1,284	1,811	1,712	1,249	777	442	241	130	71	39	23	13	8	5	3	2	2
94											9	149	749	1,615	1,958	1,624	1,059	598	313	159	80	41	22	12	7	4	3	2	1	1
93											19	259	1,063	1,921	2,002	1,457	849	435	209	99	47	23	12	6	3	2	1	1		
92										1	40	426	1,427	2,163	1,936	1,237	644	300	133	58	26	12	6	3	2	1	1			
91										2	78	664	1,812	2,303	1,771	993	462	195	80	33	14	6	3	1	1					
90										4	147	979	2,177	2,319	1,533	754	314	120	45	17	7	3	1	1						
89										10	259	1,365	2,474	2,210	1,255	542	201	70	24	9	3	1	1							
88										23	434	1,801	2,660	1,992	972	368	122	39	12	4	1	1								
87										47	687	2,247	2,704	1,698	712	237	70	20	6	2	1									
86									1	93	1,028	2,652	2,601	1,370	494	144	38	10	3	1										
85									3	174	1,455	2,961	2,367	1,045	324	83	20	5	1											
84									6	307	1,950	3,128	2,037	754	201	45	10	2												
83									14	512	2,470	3,125	1,659	515	118	23	4	1												
82									31	809	2,961	2,953	1,278	333	65	11	2													
81									64	1,209	3,358	2,640	931	203	34	5	1													
80								1	125	1,709	3,602	2,233	642	117	17	2														
79								2	231	2,285	3,654	1,787	418	64	8	1														
78								4	402	2,890	3,508	1,352	258	33	4															
77								9	664	3,459	3,185	968	151	16	1															
76								21	1,035	3,915	2,735	655	83	8	1															
75								45	1,528	4,192	2,222	420	43	3																
74								92	2,132	4,246	1,708	254	21	1																
73								175	2,816	4,069	1,242	146	10	1																
72								318	3,517	3,688	854	79	4																	
71							1	545	4,155	3,162	556	41	2																	
70							2	884	4,644	2,565	342	20	1																	
69							4	1,357	4,910	1,968	199	9																		
68							11	1,970	4,911	1,428	110	4																		
67							27	2,705	4,647	981	57	2																		
66							63	3,514	4,159	637	28	1																		
65							134	4,318	3,521	391	13																			
64							268	5,019	2,820	227	6																			
63							502	5,518	2,136	125	2																			
62							880	5,740	1,531	65	1																			
61							1,445	5,647	1,038	32																				
60						1	2,220	5,256	666	15																				
59						3	3,193	4,628	404	7																				
58						10	4,298	3,854	232	3																				
57						28	5,415	3,037	126	1																				
56						71	6,386	2,263	65																					
55						165	7,049	1,595	31																					
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53						701	7,045	671	6																					
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51					5	2,162	5,404	226	1																					
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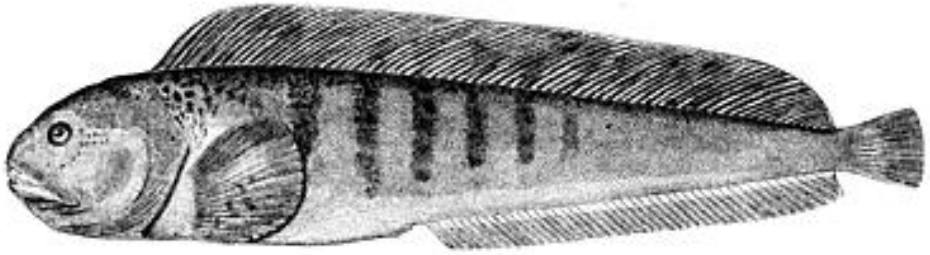
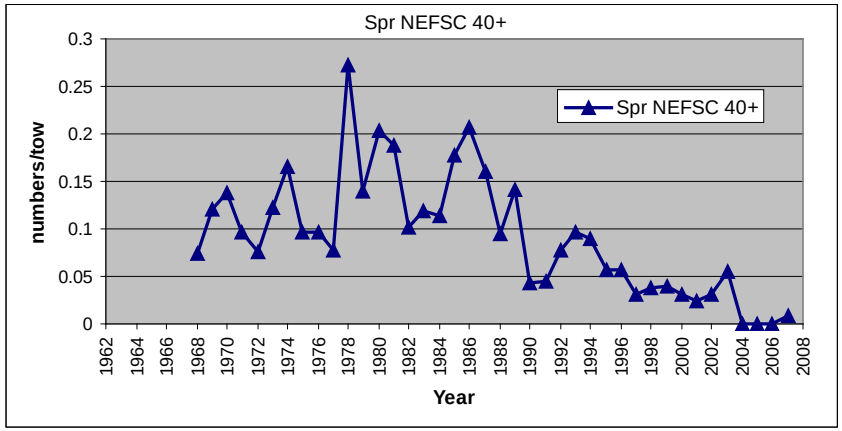
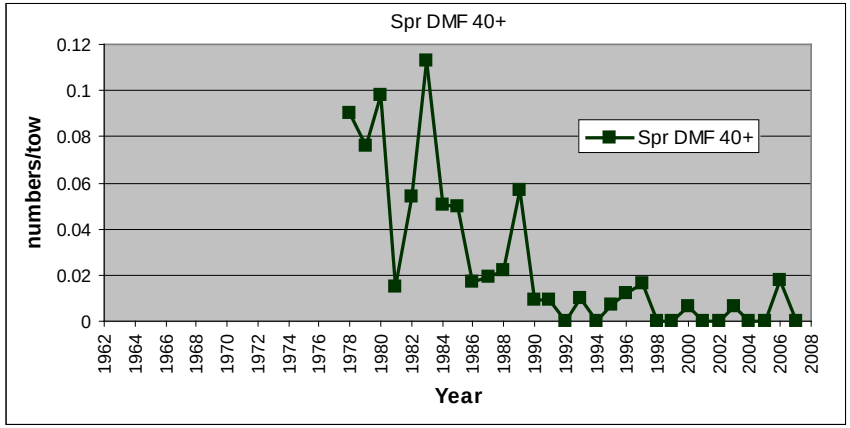
49					50	4,844	3,182	61																						
48					134	6,431	2,211	29																						
47					328	7,880	1,438	13																						
46					725	8,914	876	6																						
45					1,453	9,308	499	2																						
44					2,638	8,973	266	1																						
43				1	4,341	7,984	133																							
42				4	6,470	6,558	62																							
41				16	8,736	4,973	27																							
40				55	10,688	3,481	11																							
39				169	11,845	2,249	4																							
38				460	11,893	1,342	2																							
37				1,106	10,818	739	1																							
36				2,345	8,915	375																								
35				4,391	6,656	176																								
34			1	7,254	4,502	76																								
33			4	10,575	2,759	31																								
32			21	13,606	1,531	11																								
31			89	15,448	770	4																								
30			310	15,479	351	1																								
29			923	13,688	145																									
28			2,333	10,681	54																									
27			5,010	7,356	18																									
26			9,135	4,470	6																									
25		3	14,150	2,398	2																									
24		20	18,616	1,135																										
23		106	20,801	474																										
22		457	19,743	175																										
21		1,584	15,915	57																										
20	1	4,395	10,897	16																										
19	5	9,765	6,337	4																										
18	35	17,376	3,130	1																										
17	178	24,756	1,313																											
16	730	28,243	468																											
15	2,399	25,801	142																											
14	6,311	18,873	36																											
13	13,295	11,055	8																											
12	22,428	5,185	1																											
11	30,295	1,947																												
10	32,767	586																												
9	28,379	141																												
8	19,681	27																												
7	10,929	4																												
6	4,860	1																												
5	1,730																													
4	493																													
3	113																													
2	21																													
1	3																													

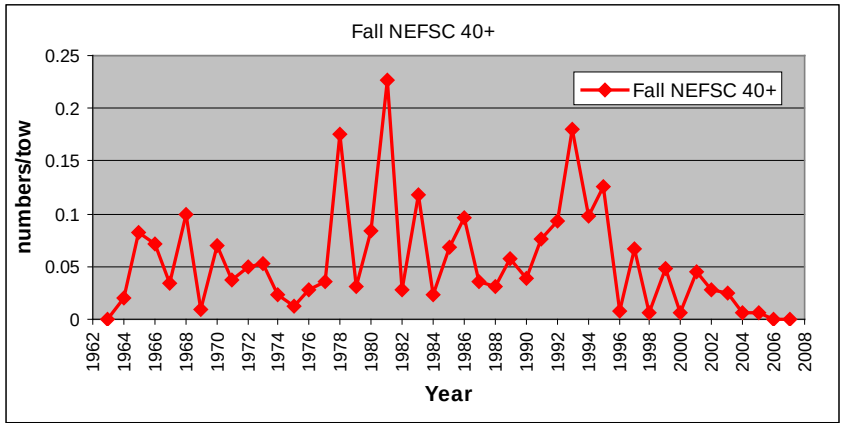
Wolffish Growth



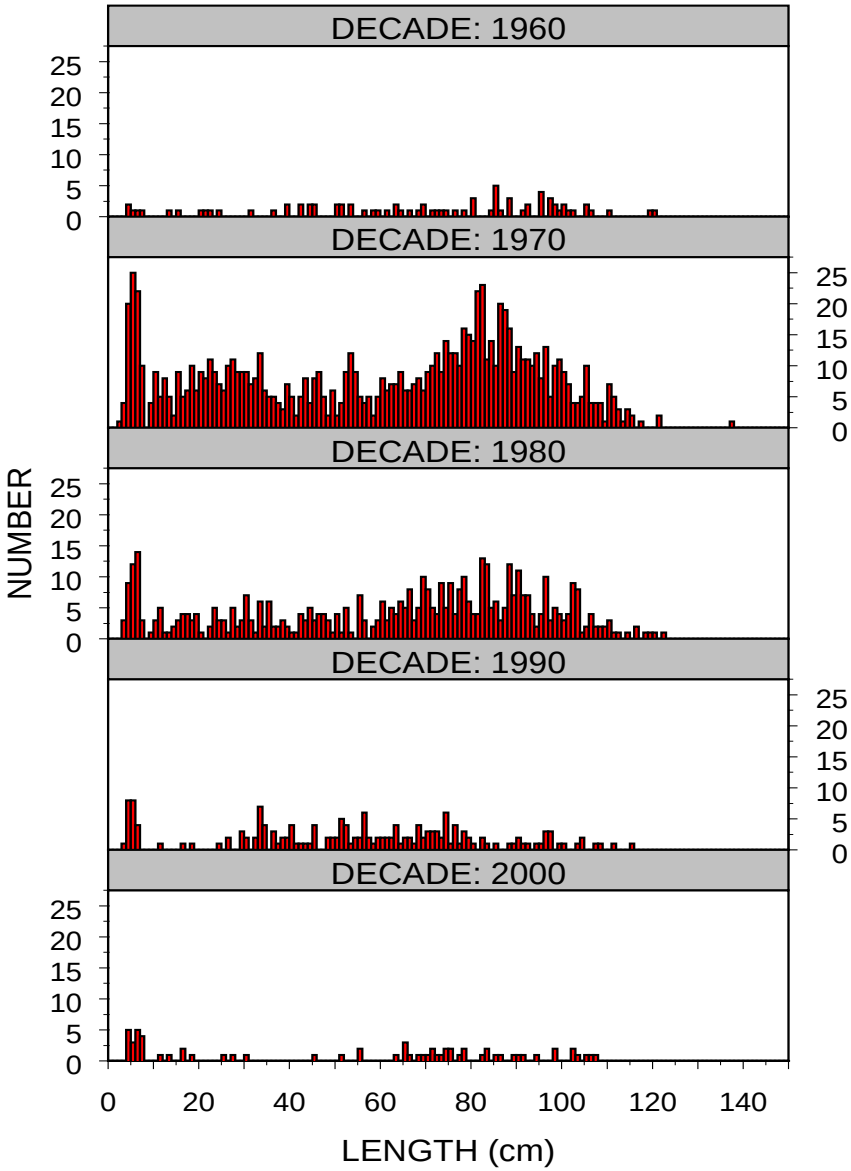
Survey Indices



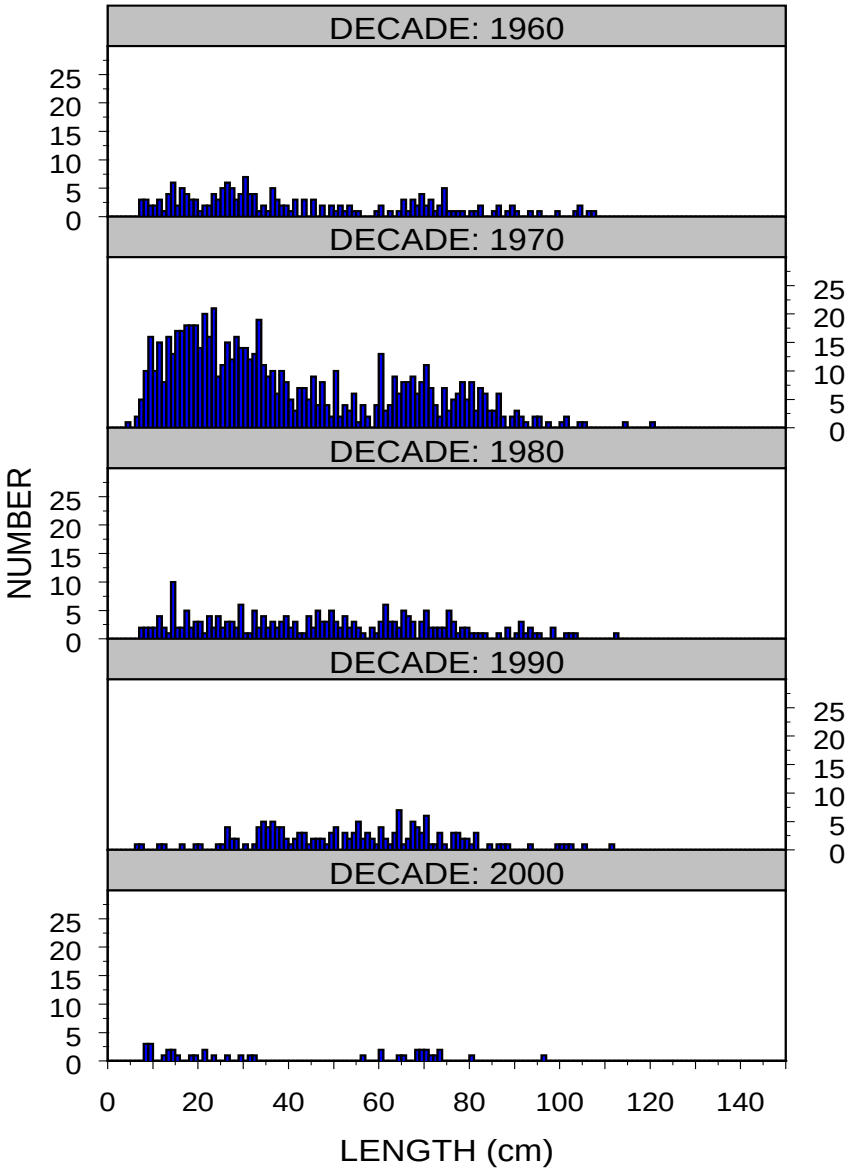




Spring Survey Length Distribution - Number



Fall Survey Length Distribution - Number



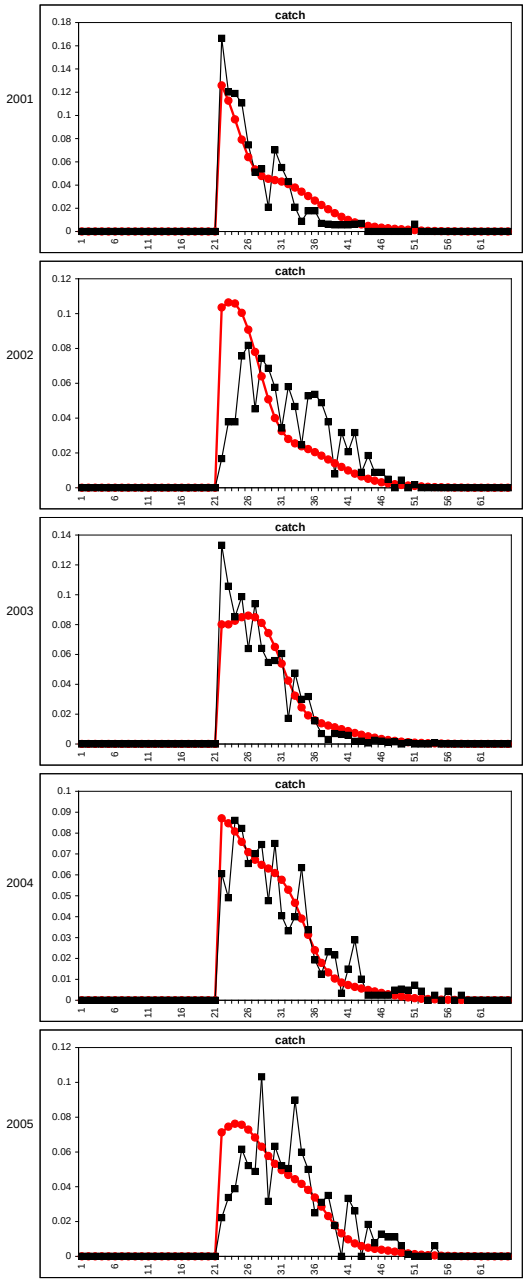
Data Poor Wolffish
What do we think we know?

Decline in the 40+ cm indices

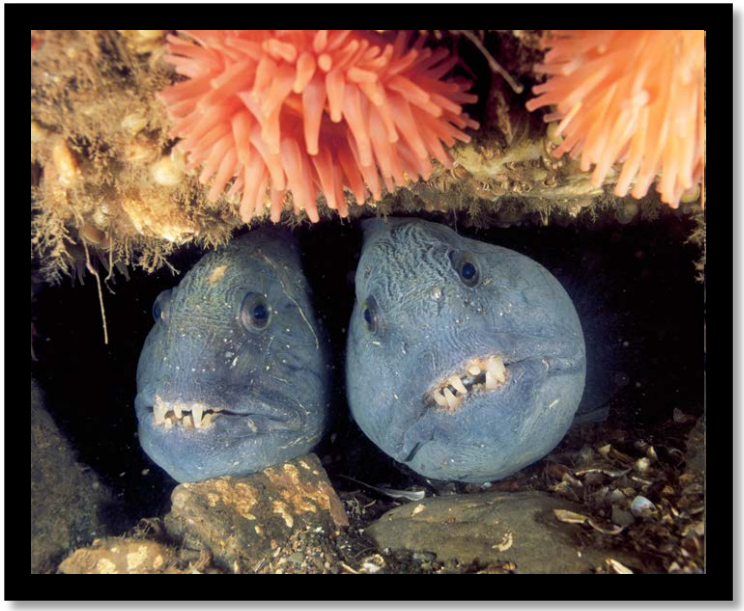
Decline in catch since 1983

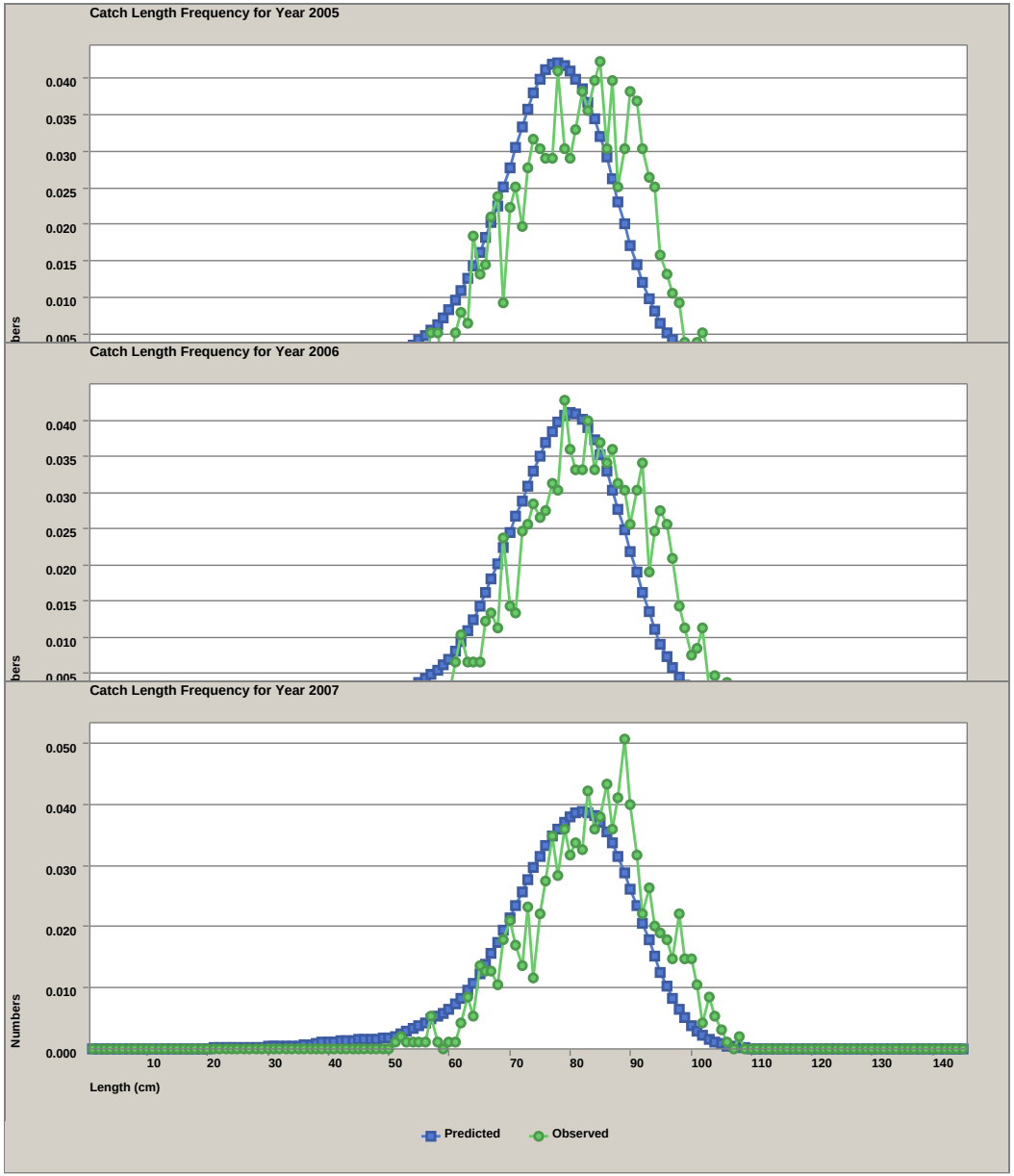
No evidence of size truncation in the catch length distributions over time

Overall growth and longevity



Spring survey Length frequency 2001-2005

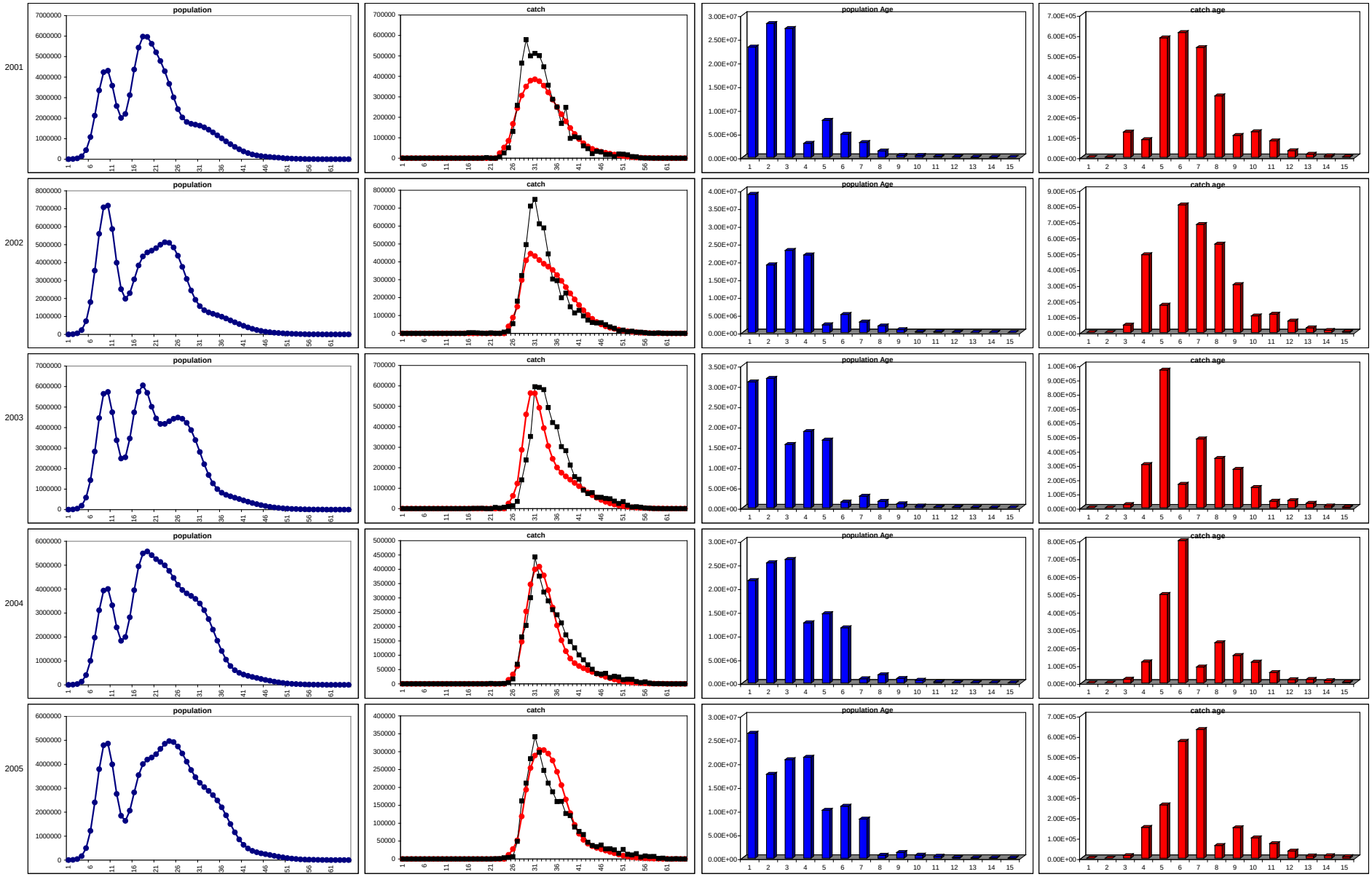




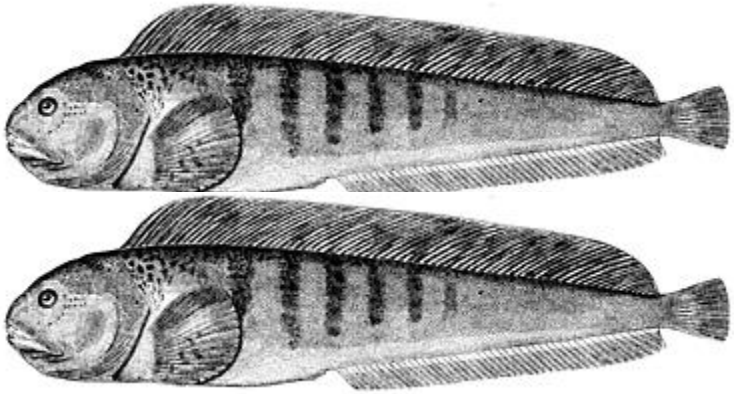
Catch Numbers Length Frequency, Year 2005

Catch Numbers Length Frequency, Year 2006

Catch Numbers Length Frequency, Year 2007


2001
2002
2003
2004
2005
population
catch
population Age
catch age

Wolffish SCALE Conclusion

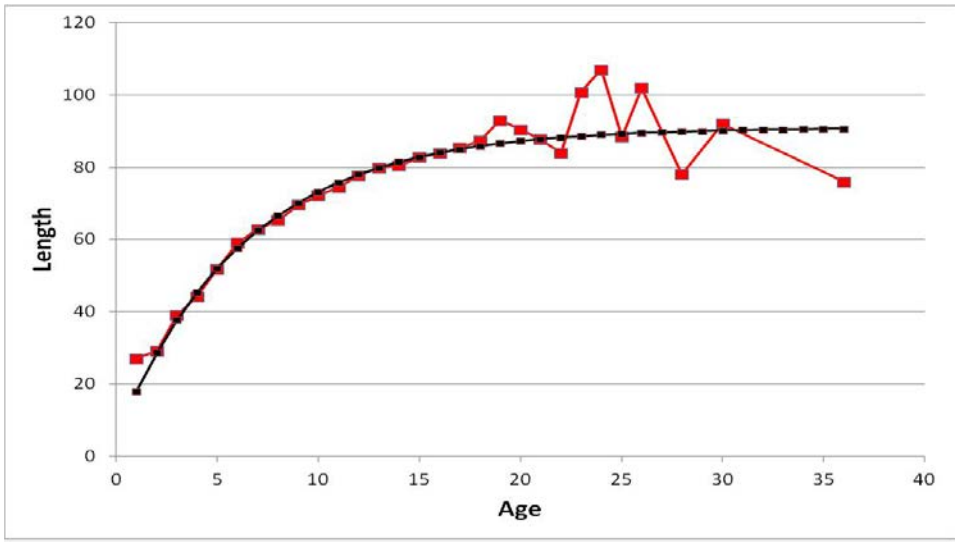


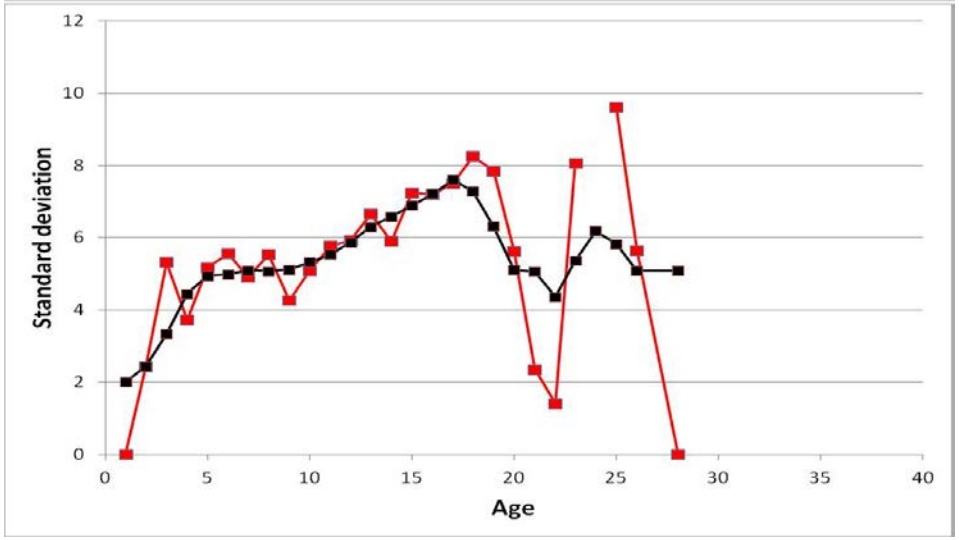
A large decline in the population biomass has occurred over the time series due to a long term declining trend in recruitment. Fishing mortality has also declined with decreases in catch since there is no evidence of size truncation in both the catch and survey distributions.

Comparison of SCALE and ASAP with a data poor stock (golden tilefish) assuming flat-topped selectivity

Assessment time series 1971-2013
Commercial age data 2007-2012
(3579 aged fish)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	total
23		1																																			1
24		1																																			1
25		2																																			2
26		2																																			2
27	2	3	2																																		7
28		8																																			8
29		5	1																																		6
30		8	4	1																																	13
31		8																																			8
32		4	5																																		9
33		1	3																																		4
34			2	2																																	4
35		1	5	1																																	7
36			4	2																																	6
37			4	7	1																																12
38			6	11																																	17
39			2	23	2																																27
40			6	39	3																																48
41			3	26	5	1																															35
42			2	47	8	1																															58
43			6	44	11																																61
44			10	60	13	2	1																														86
45			8	56	32	2	1																														99
46			4	64	31	6	1																														106
47			1	42	42	5	3	2																													95
48				31	53	11	3																														98
49				18	58	15	3		1																												95
50				7	80	16	1	1		1																											106
51				8	59	12	5	2			1																										87
52				5	66	25	5	1																													102
53				3	56	20	8	2																													89
54				5	47	22	8	2																													84
55				2	44	31	4	1																													82
56				2	34	38	11	4																													89
57					29	52	5	4																													90
58				1	22	53	14	3																													93
59					19	44	17	6	1																												87
60					13	38	23	3			1																										78
61					11	45	27	2																													85
62					16	47	43	3	2	1																											112
63					12	47	37	12	1	1																											110
64					5	34	54	4		1	1																										99
65					2	31	55	16	4	1		1																									110
66					5	38	37	11	2		1																										94
67					2	19	49	25	3	3																											101
68					1	21	23	27	12		3	2	1																								90
69					1	10	20	17	26	15	2																										91
70						3	8	9	13	32	6	3			1																						75
71							3	7	12	15	9	17		1		1																					65
72						1	1	3	1	12	11	8	7	1	2																						47
73								2	5	12	4	9	10			1	1	1																			45
74							1	1	2	6	11	11	10	4	2	1																					49
75									2	7	10	6	12	7	3	1		1																			49
76									1	3	5	15	7	6	8	3	1																			1	50
77								2	1	4	3	8	5	5	2	2																					32
78										2	6	11	8	8	7	2	4	1							1			2									52
79									1	2	6	7	5	6	3	4	2																				36
80									3	2		5	6	3	10	1	1		1																		32
81									1	1	1	7	2	2	1	4		1																			20
82										1		4	6	1	2	4		1																			19
83												2	2	4	2	2	3	2		1		1															19
84								1		3	2	2	2	3	3	2	3																				21
85										1	2	5	1	3	1	4		1	1			1															20
86										1	1	2	5	1	5	2				1	2																20
87										1	2	3	3	1	2	1	1	1		1																	16
88											1	4	4		2	2	1	1			1																16
89												4	3	1	3	1	3	3					1														19
90											1	3	2	2	2	1				1					1												13
91												1	1	3	1	3	1		1		1																12
92													2	1	3			2	1	1										1							11
93												2	2			1			1																		6
94										1			2	1	2	1	2	1																			10
95													1		1	1	1																				4
96													1					1																			2
97													1							1					1												3
98															1			1		1						1											4
99														1			1																				2
100															1	1			1																			3
101															2	1			1																			4
102																1			1				1															3
103																	1																					1
104																																					
105																																					
106																							2			1											3
107																		1						1													2
	2	44	78	507	783	690	471	173	94	132	89	141	110	65	72	48	26	19	8	7	4	2	4	1	3	2		2		1						1	3579





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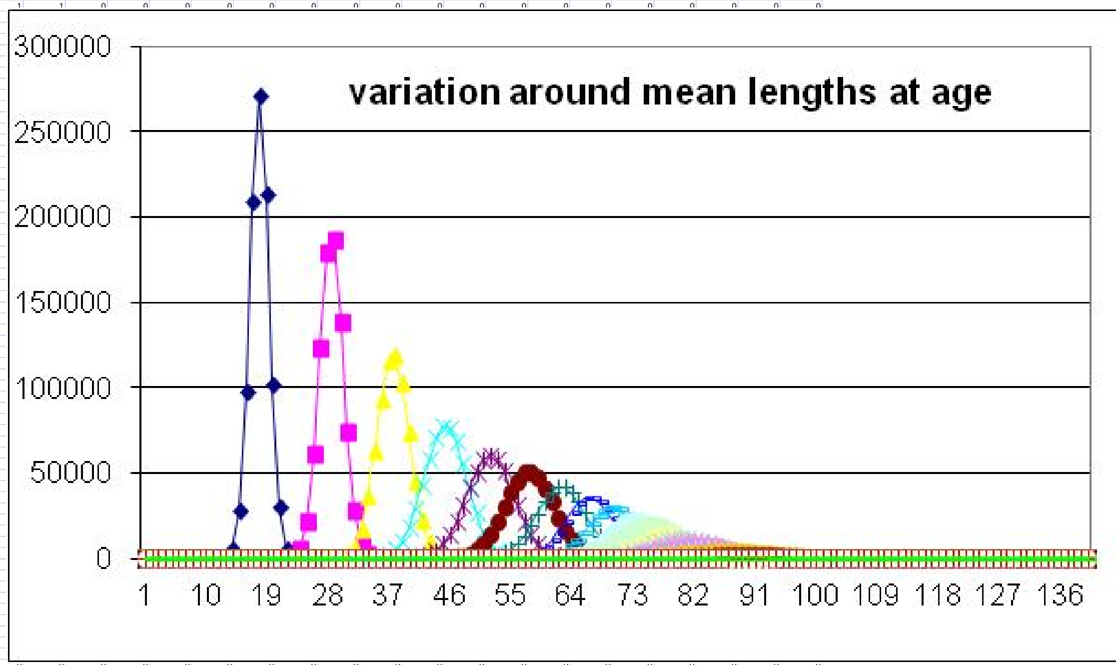
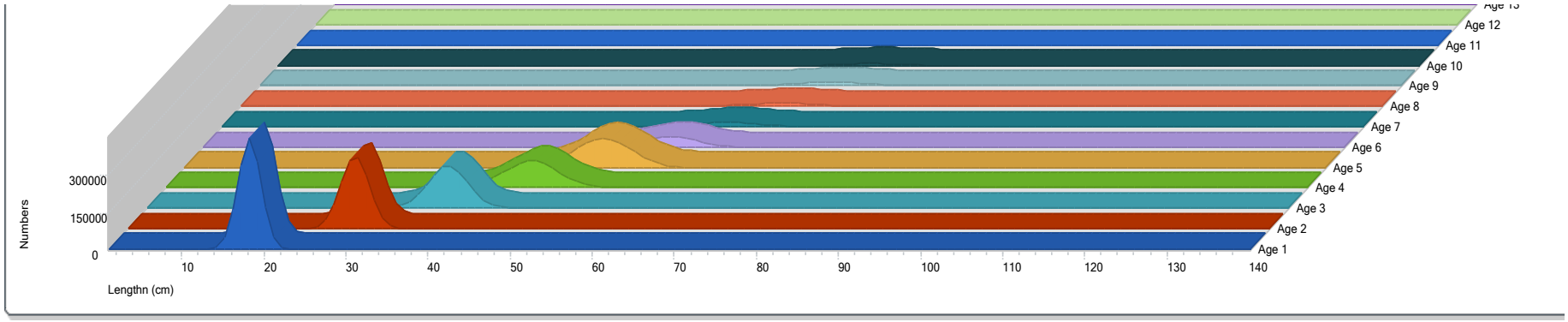
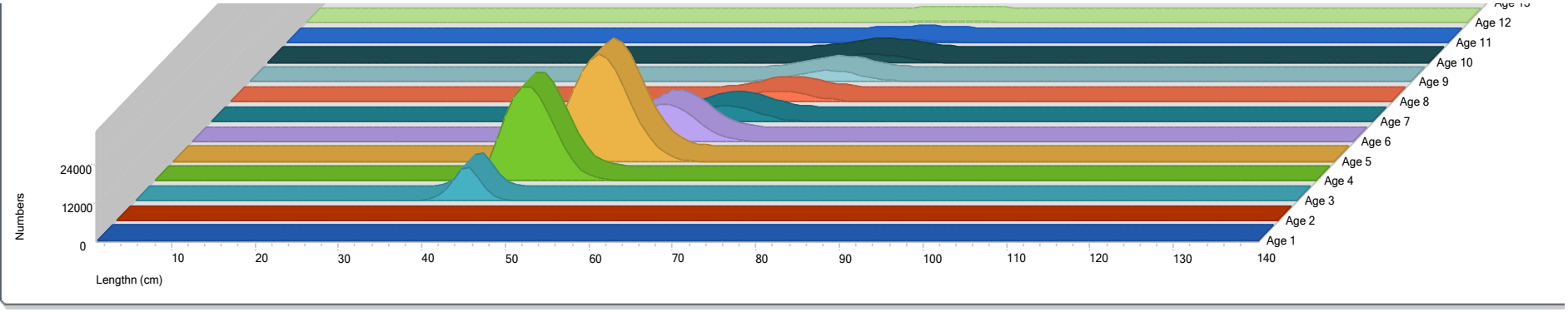


Predicted population numbers and length and age



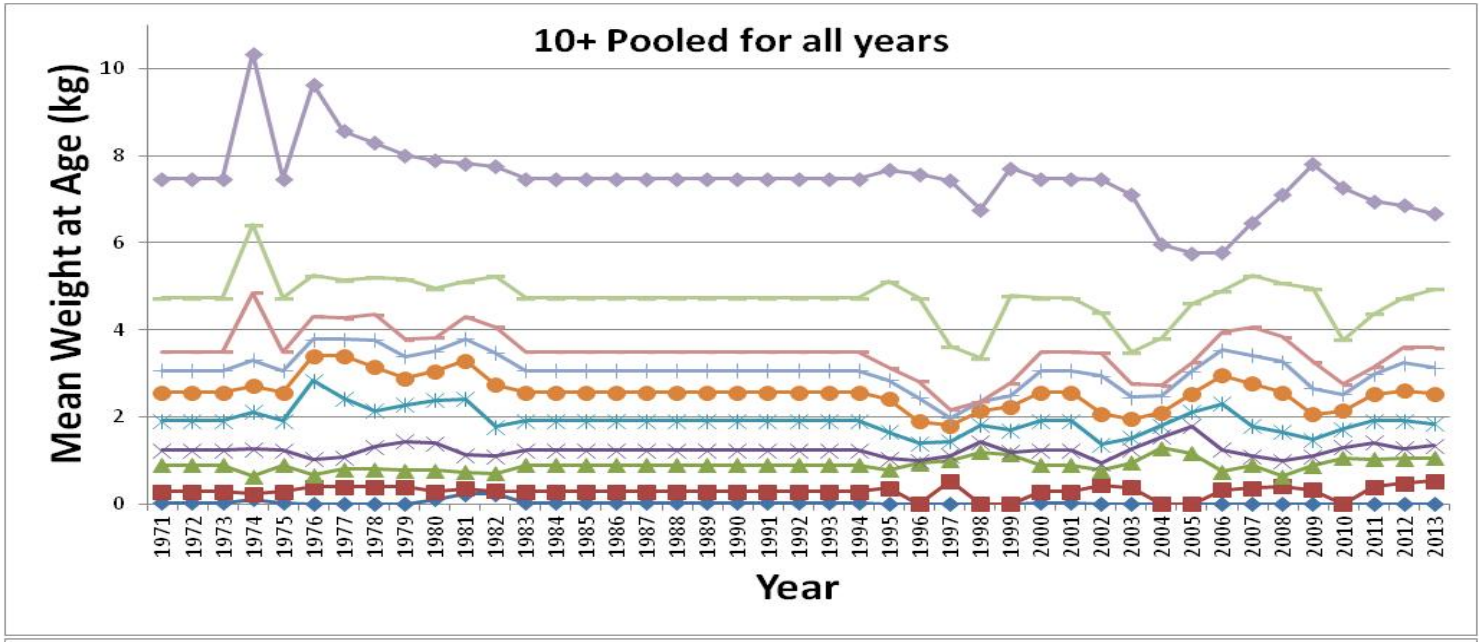
Predicted catch numbers and length and age



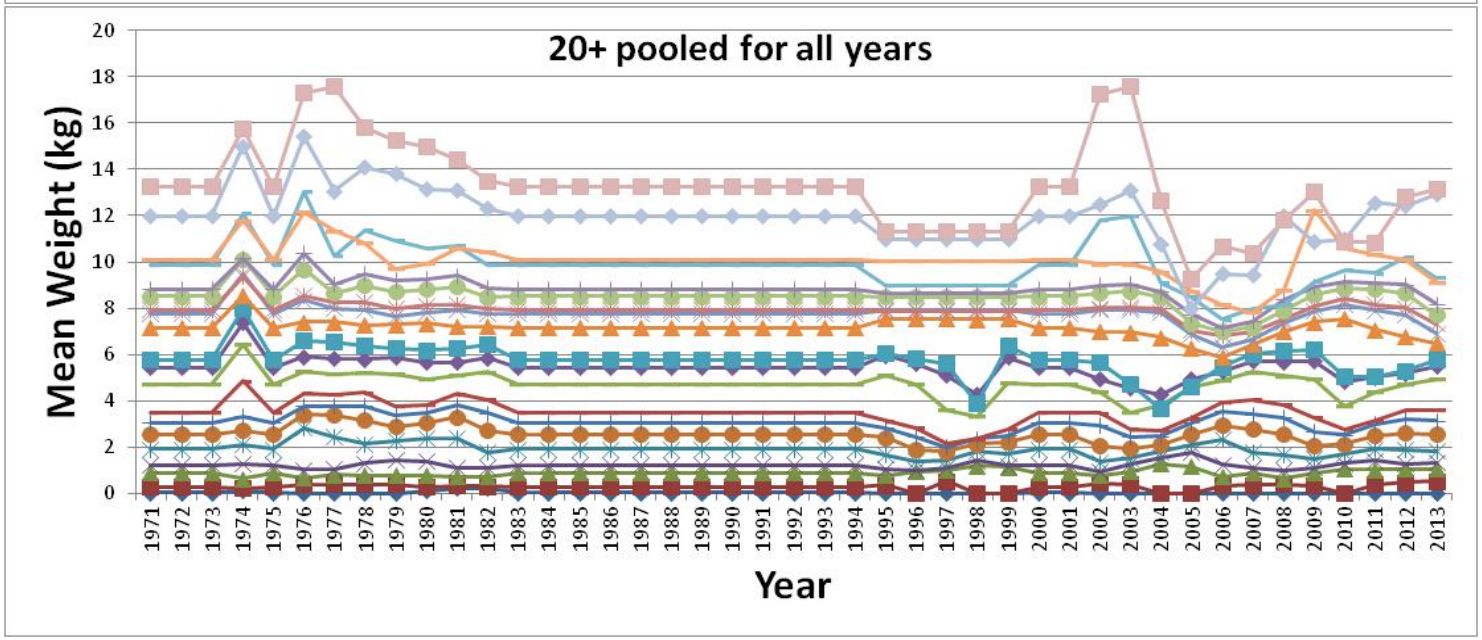
SCALE & ASAP

SCALE was designed for data poor stocks which lack production age data.

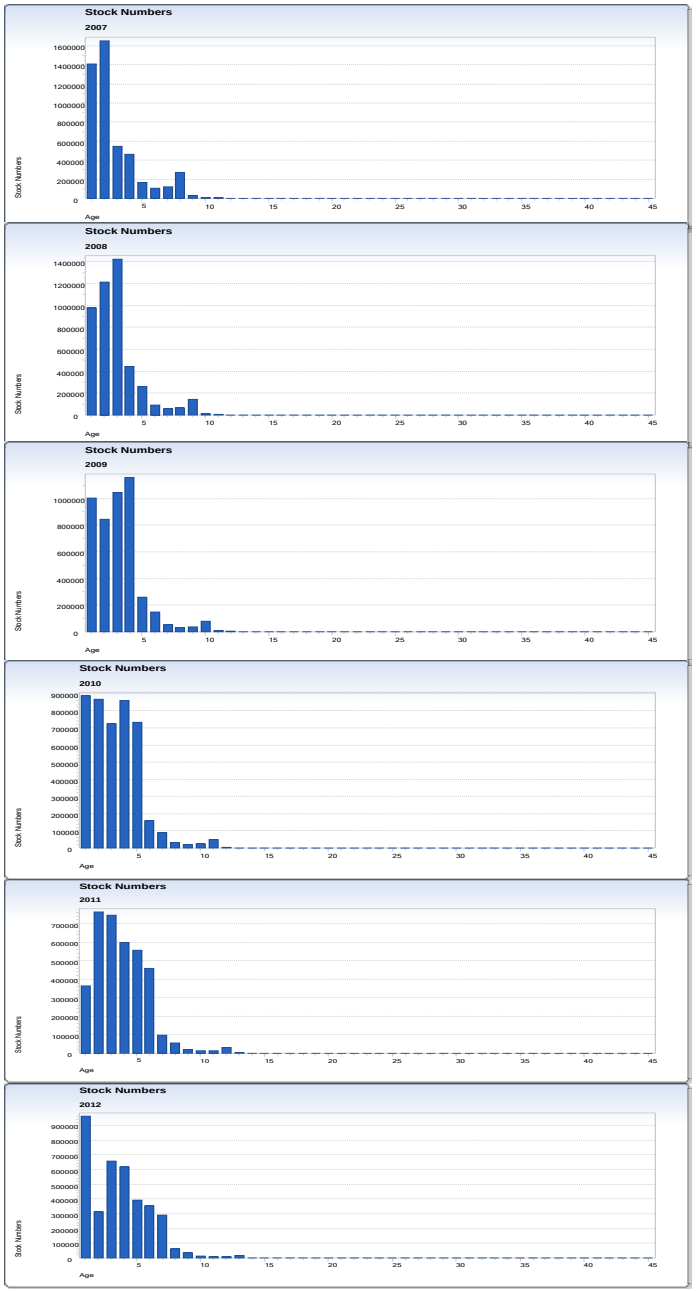
ASAP is a fully developed forward projecting age-structured model. ASAP can be configured for use with data poor stocks with the use of pooled age length-keys.



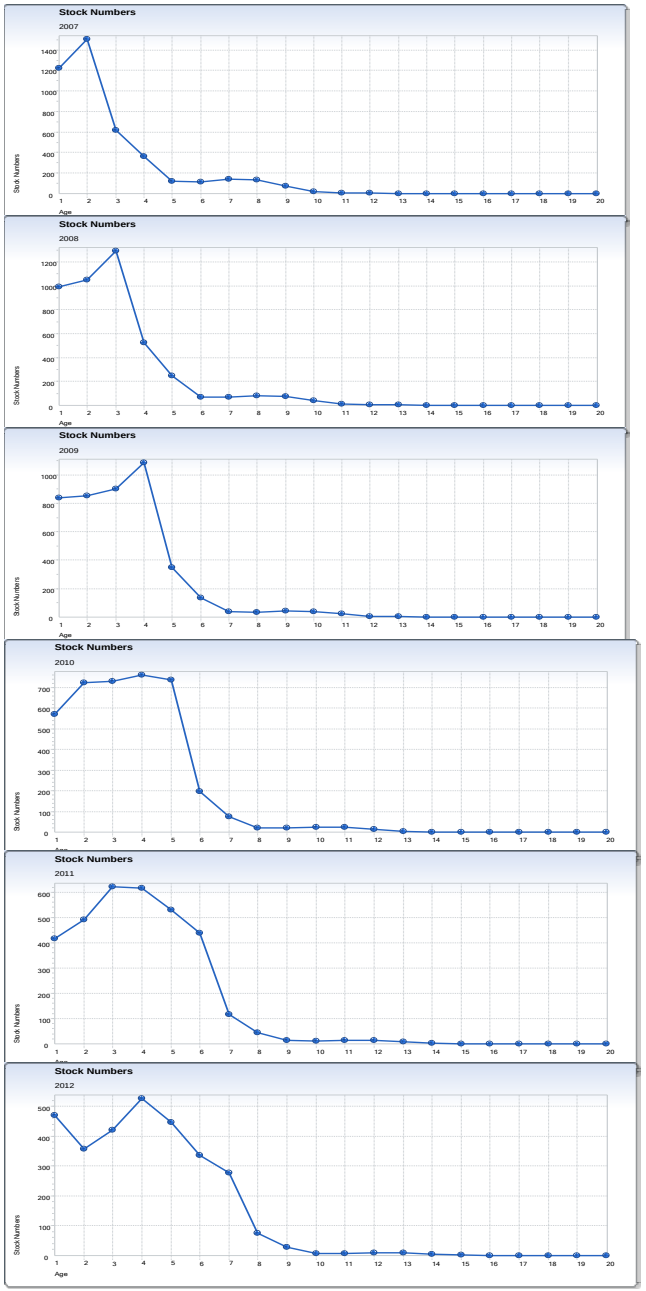
Plus Group & Mean Weights?



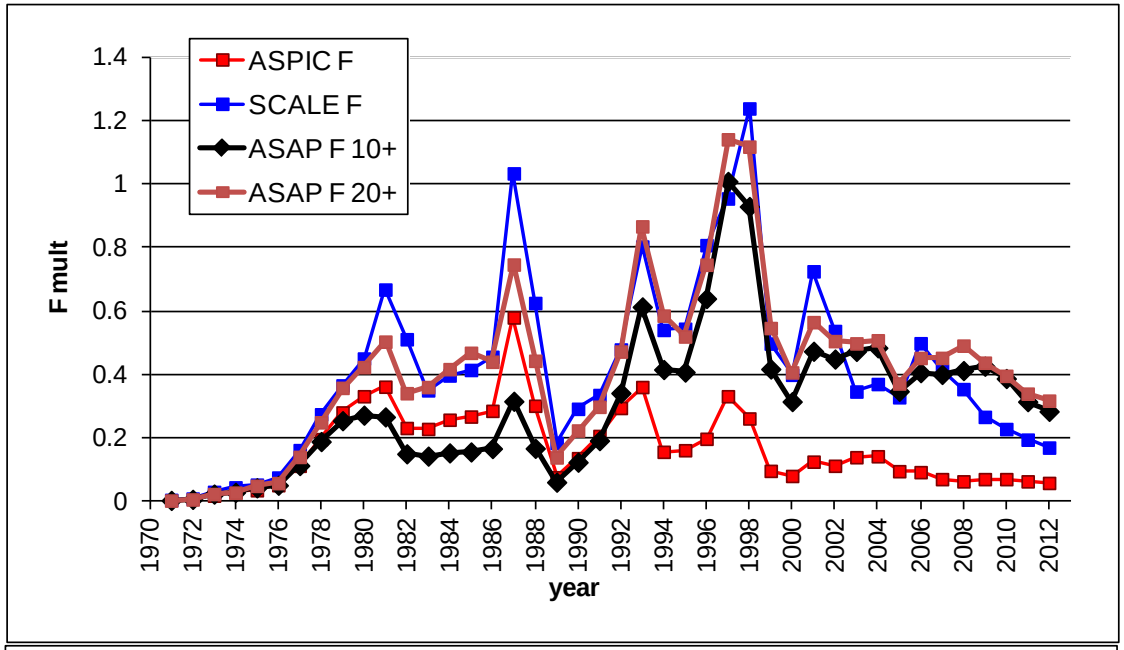
A S A P

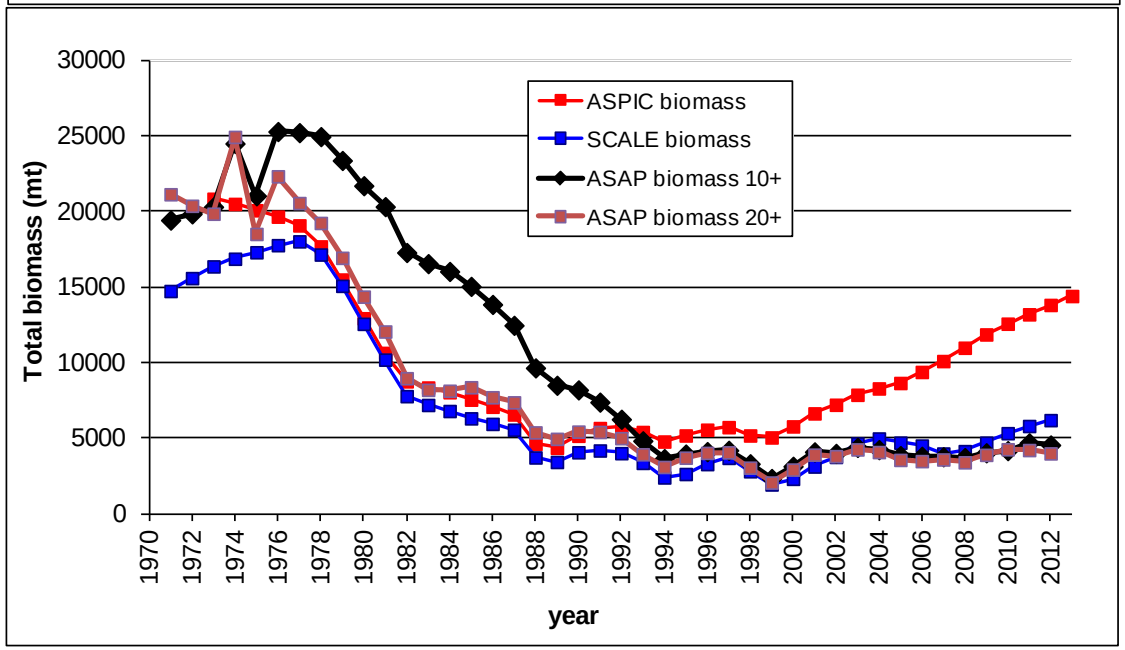

Stock Numbers
2007
Stock Numbers
2008
Stock Numbers
2009
Stock Numbers
2010
Stock Numbers
2011
Stock Numbers
2012
Stock Numbers
Age

SCALE


Stock Numbers
2007
Stock Numbers
2008
Stock Numbers
2009
Stock Numbers
2010
Stock Numbers
2011
Stock Numbers
2012
Stock Numbers
Age

ASAP





ASAP - SCALE Flat-topped Comparison

Relatively simple to use forward projecting model

Does not rely on production ageing

Incorporates multiple surveys (size and abundance trends), catch, catch at length, and growth information into a single modeling framework

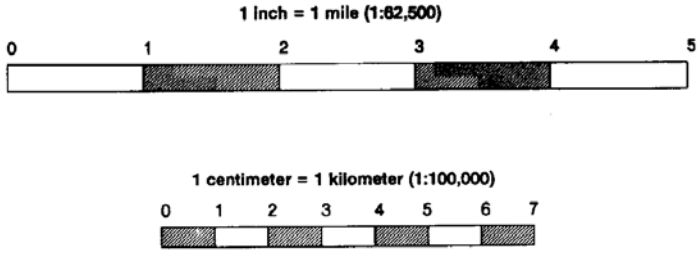
May not be useful for stocks where the catch is mostly comprised of younger fast growing individuals

Dome shaped selectivity is not an option

MCMC uncertainty has not been fully integrated into AGEPRO projections

Time constraints for R&D improvements and updates to the model

Devote more time for SCALE R&D to produce greater efficiency within stock assessments with fewer steps that are subject to errors.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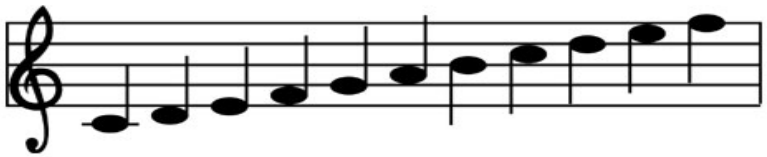
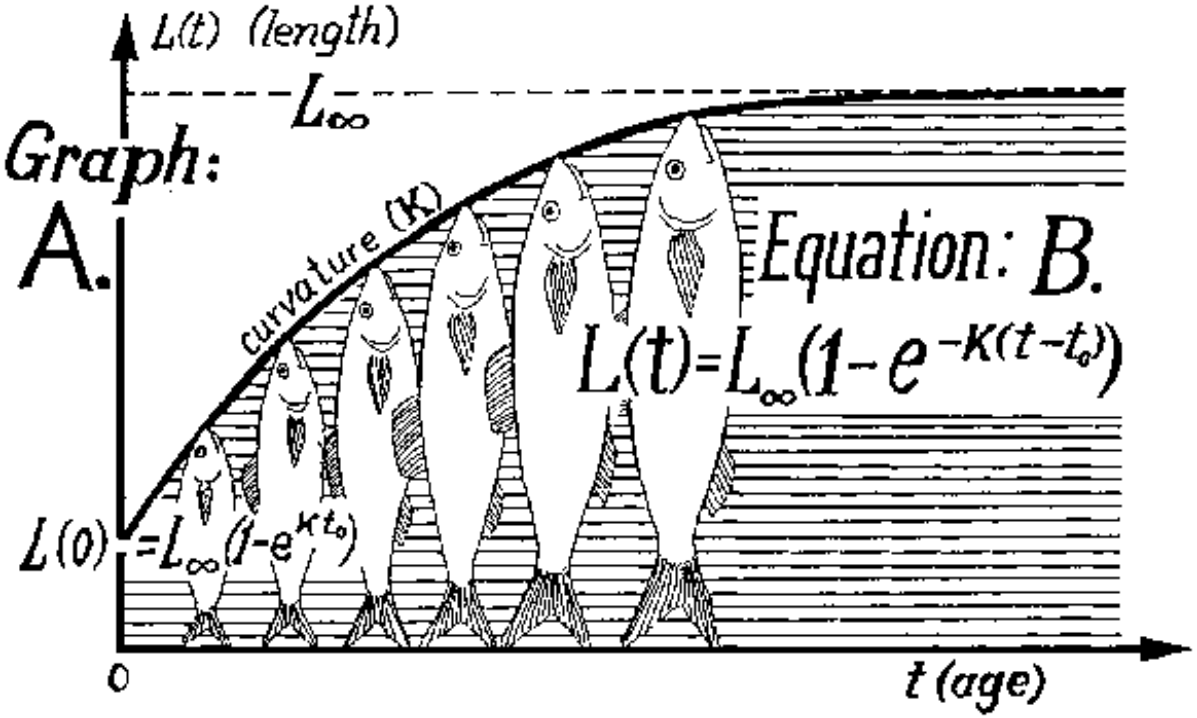
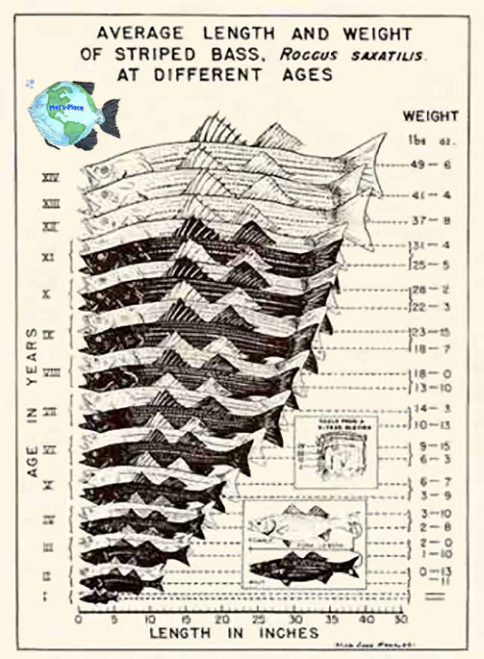
0 1 2 3 4 5
1 centimeter = 1 kilometer (1:100,000)
0 1 2 3 4 5 6 7



Questions?


L(t) (length)
L∞
Graph:
A.
curvature (K)
Equation: B.
L(t)=L∞(1-e^-K(t-t0))
L(0)=L∞(1-e^Kt0)
0
t (age)


AVERAGE LENGTH AND WEIGHT
OF STRIPED BASS, ROCCUS SAXATILIS
AT DIFFERENT AGES
WEIGHT
AGE IN YEARS
LENGTH IN INCHES