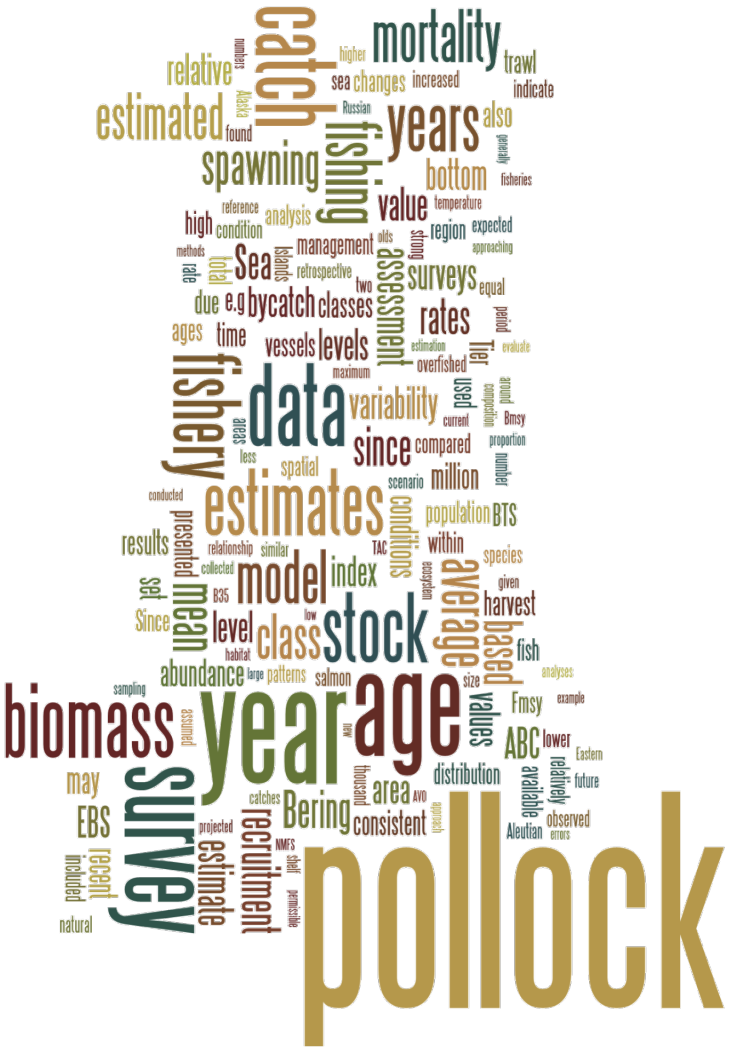

Eastern Bering Sea Pollock assessment

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Alaska Fisheries Science Center
May CIE Review 2016

Outline

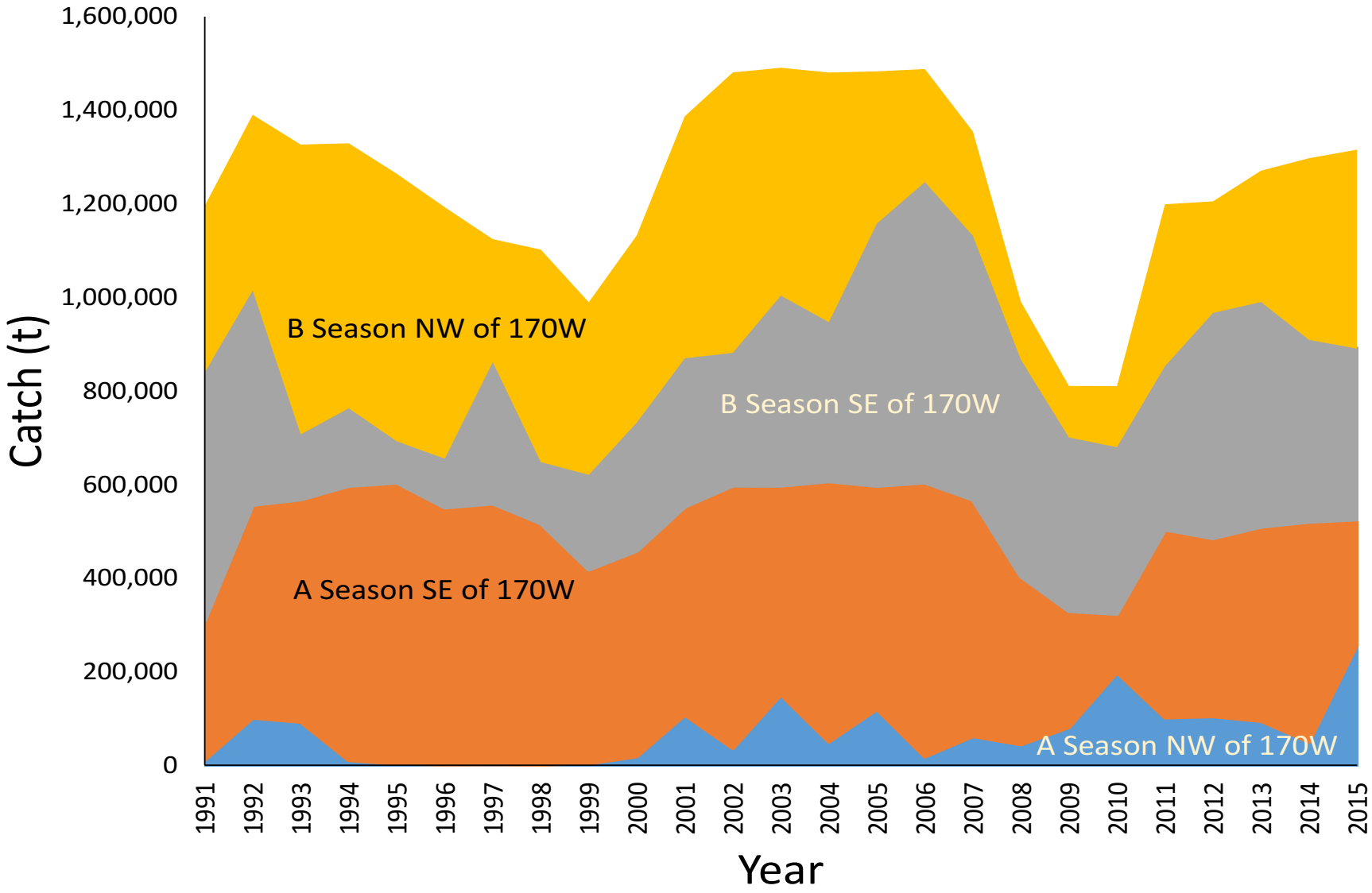
- Broad sketch of assessment as presented each year
  1. Fishery characteristics and data
  2. Survey and results and data
  3. Model results
  4. ABC/OFL approach

Data

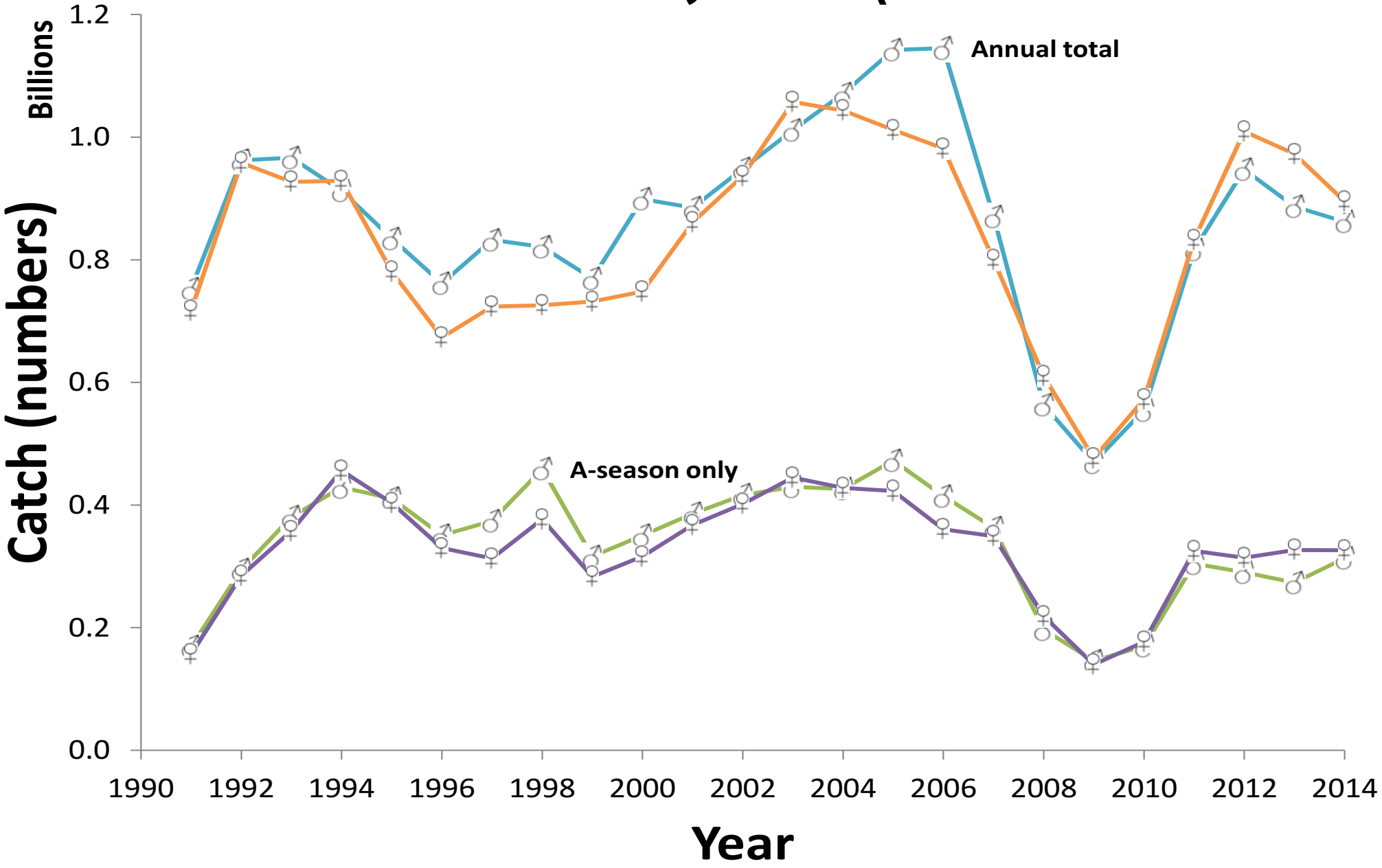
The following data were used in the assessment

Source	Type	Years
Fishery	Catch biomass	1964-2015
Fishery	Catch age composition	1964-2014
Fishery	Japanese trawl CPUE	1965-1976
EBS bottom trawl	Area-swept abundance (numbers) index by age	1982-2015
Acoustic trawl survey	Population abundance (numbers) index by age	1979, 1982, 1985, 1988, 1991, 1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006-2010, 2012, 2014
Acoustic vessels of opportunity (AVO)	Population abundance (numbers) index	2006-2015

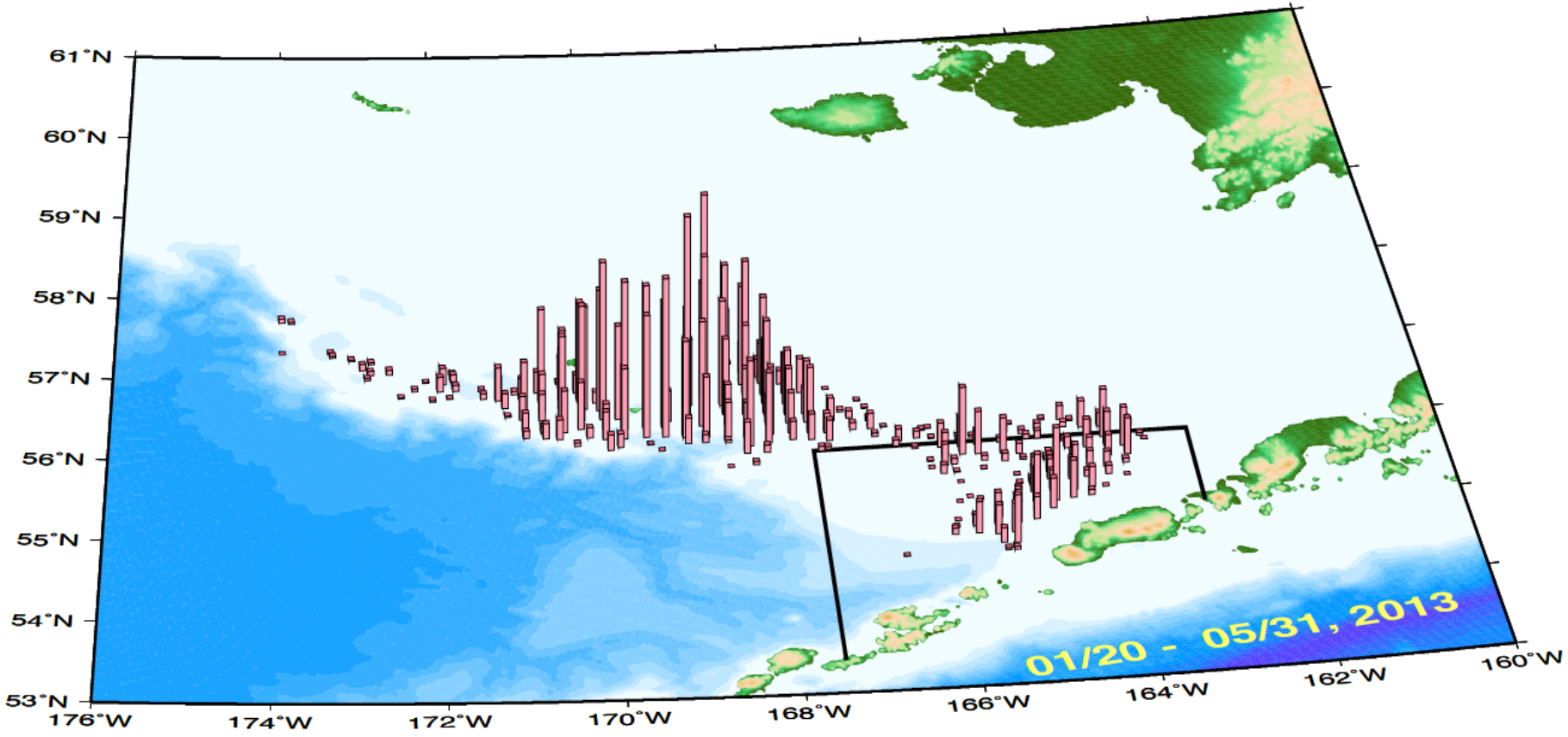
Catch by season and area



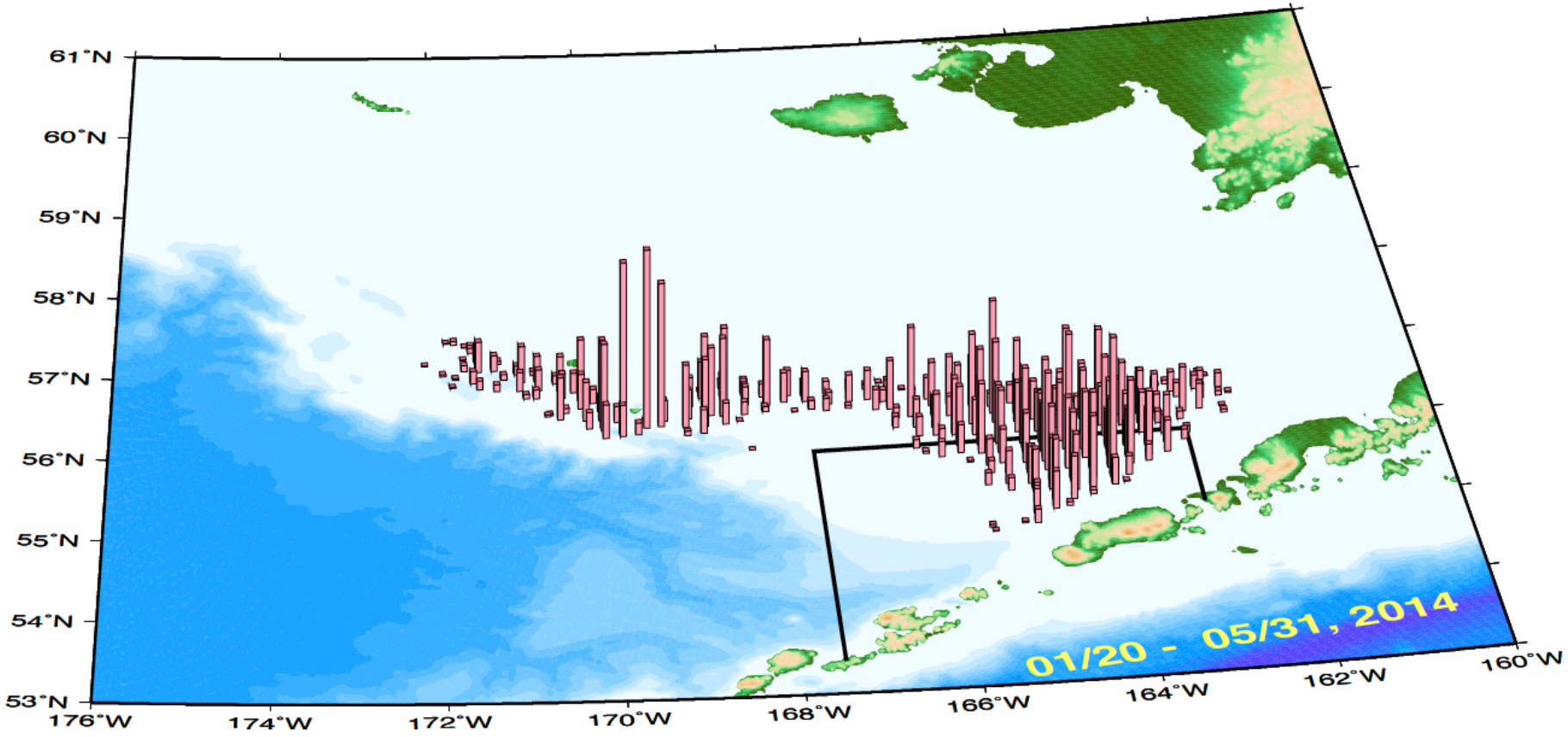
Catch numbers by sex (total and A-season)



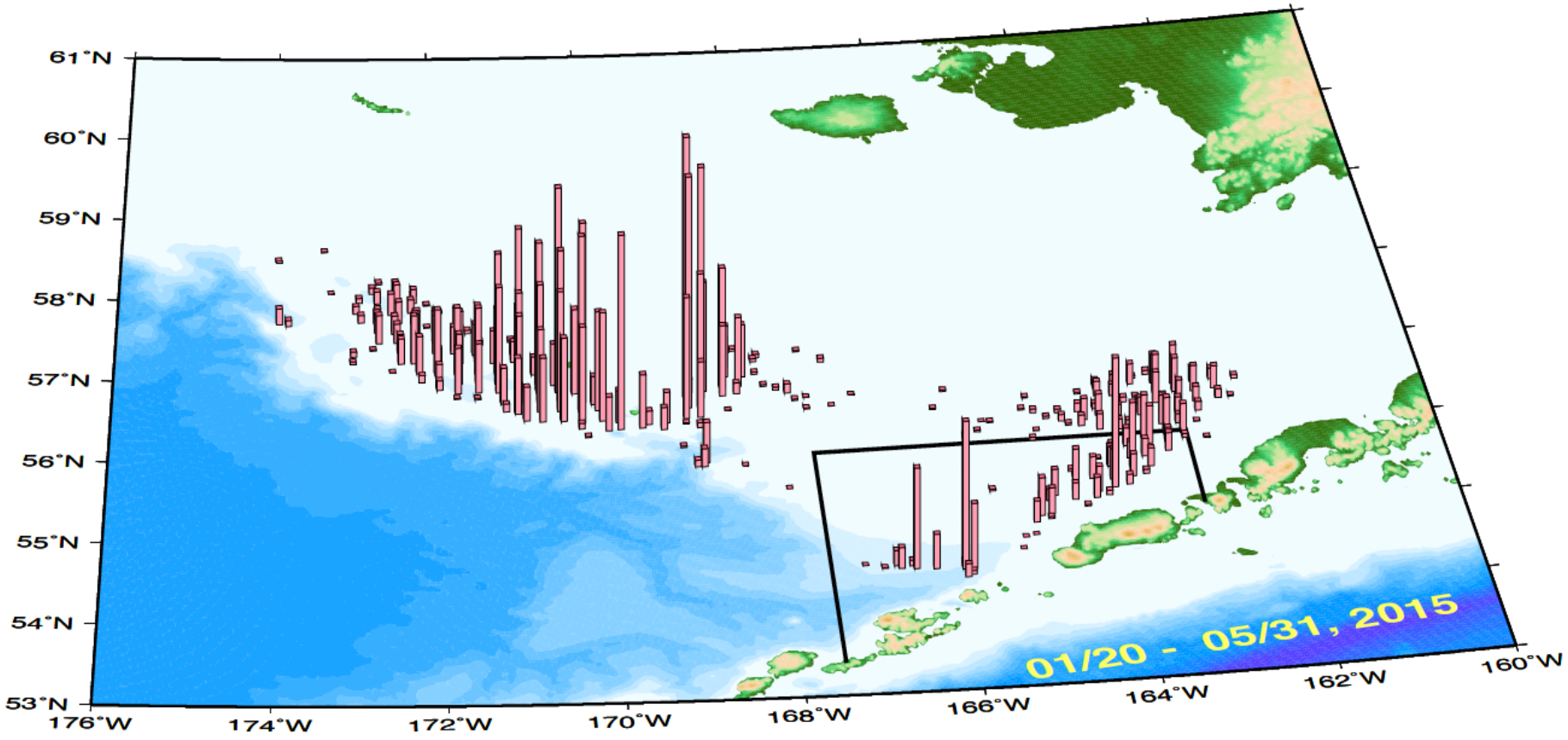
Winter 2013 fishery
Eastern Bering Sea (EBS)



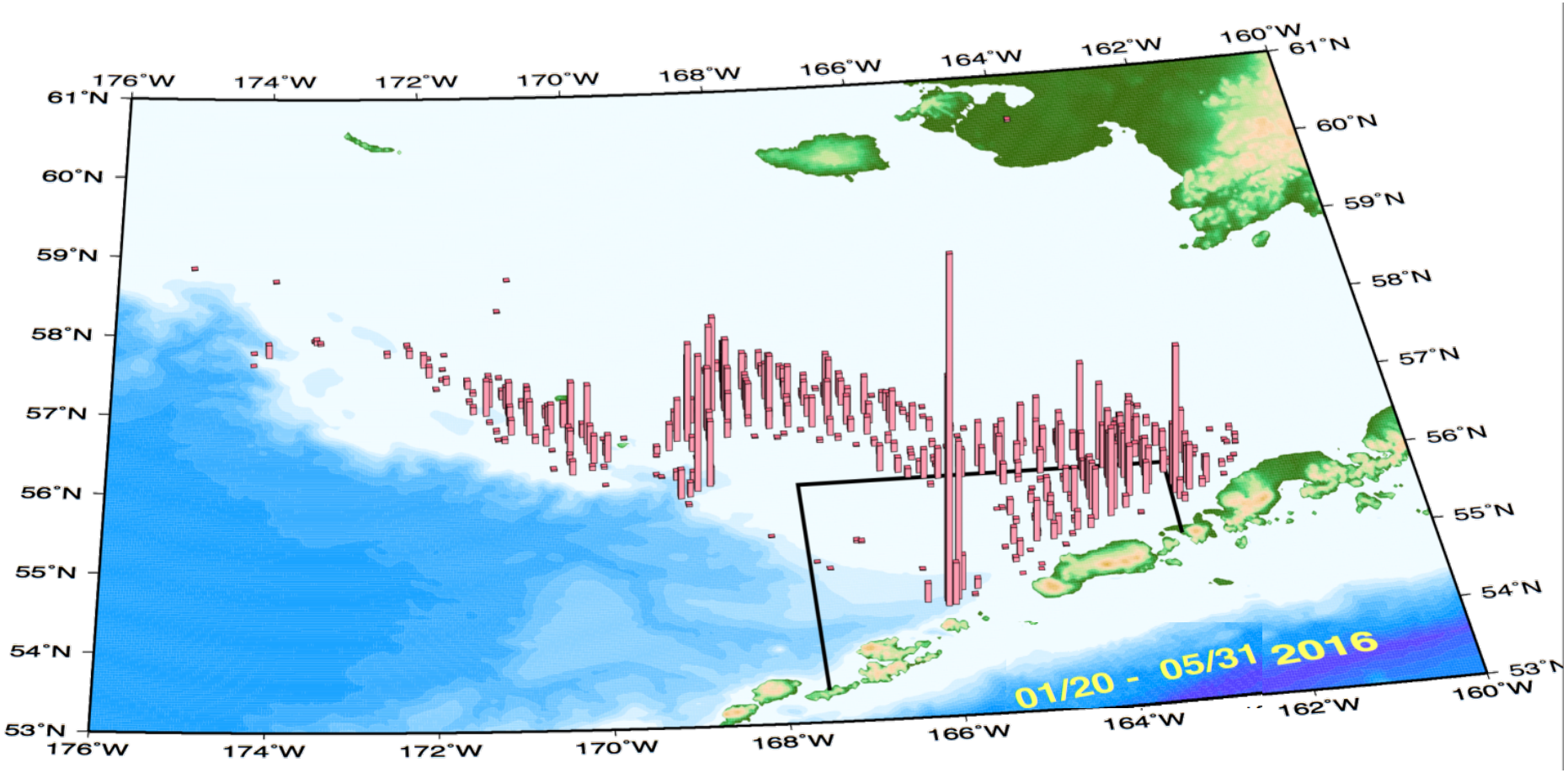
Winter 2014 fishery
Eastern Bering Sea (EBS)



Winter 2015 fishery
Eastern Bering Sea (EBS)



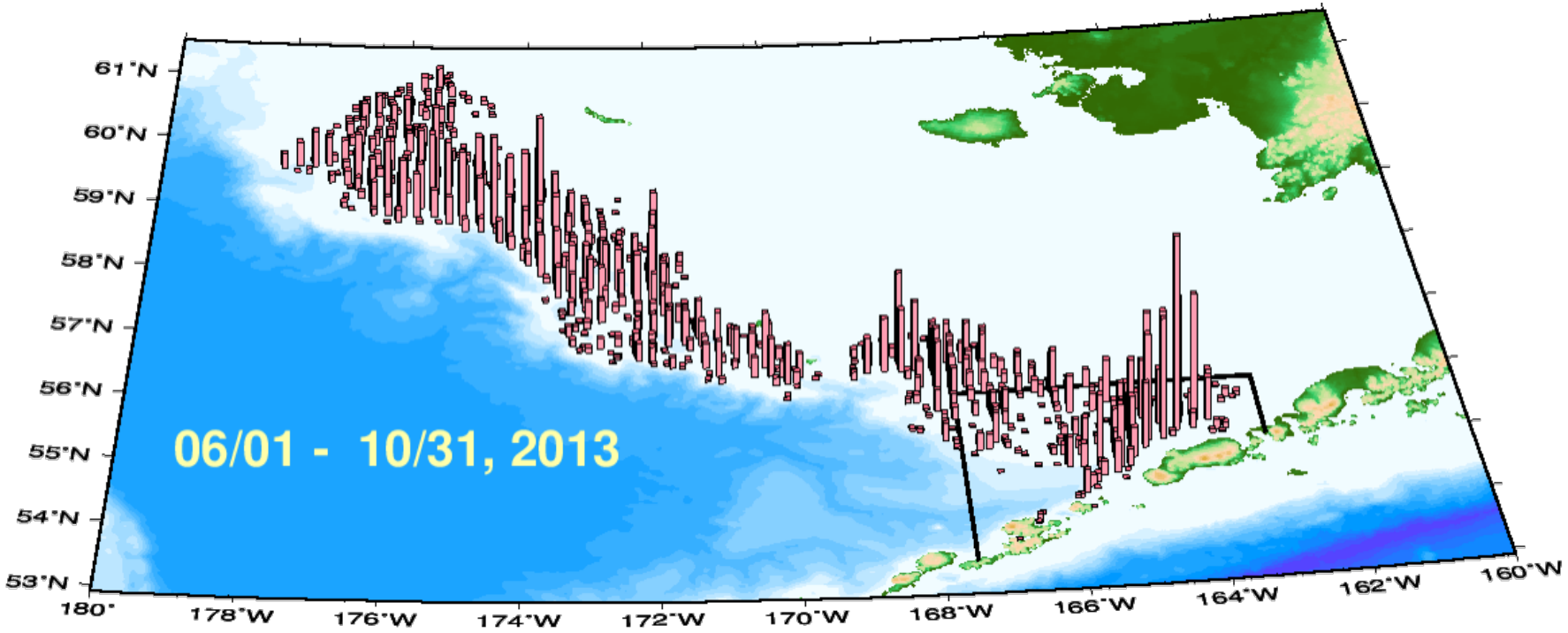
Winter 2016 fishery
Eastern Bering Sea (EBS)



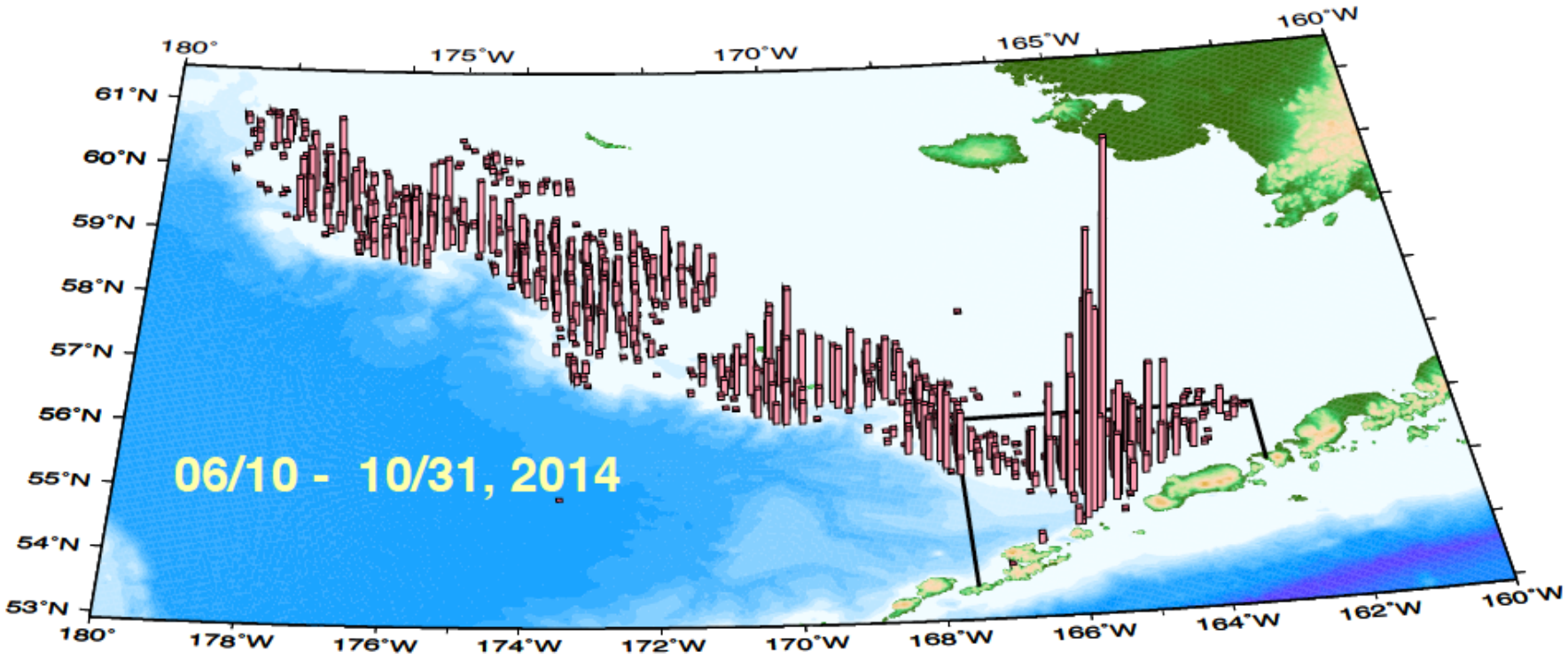
Eastern Bering Sea pollock fishery

Recent summer patterns...

Summer 2013 fishery
Eastern Bering Sea (EBS)



Summer 2014 fishery
Eastern Bering Sea (EBS)



Summer 2015 fishery
Eastern Bering Sea (EBS)

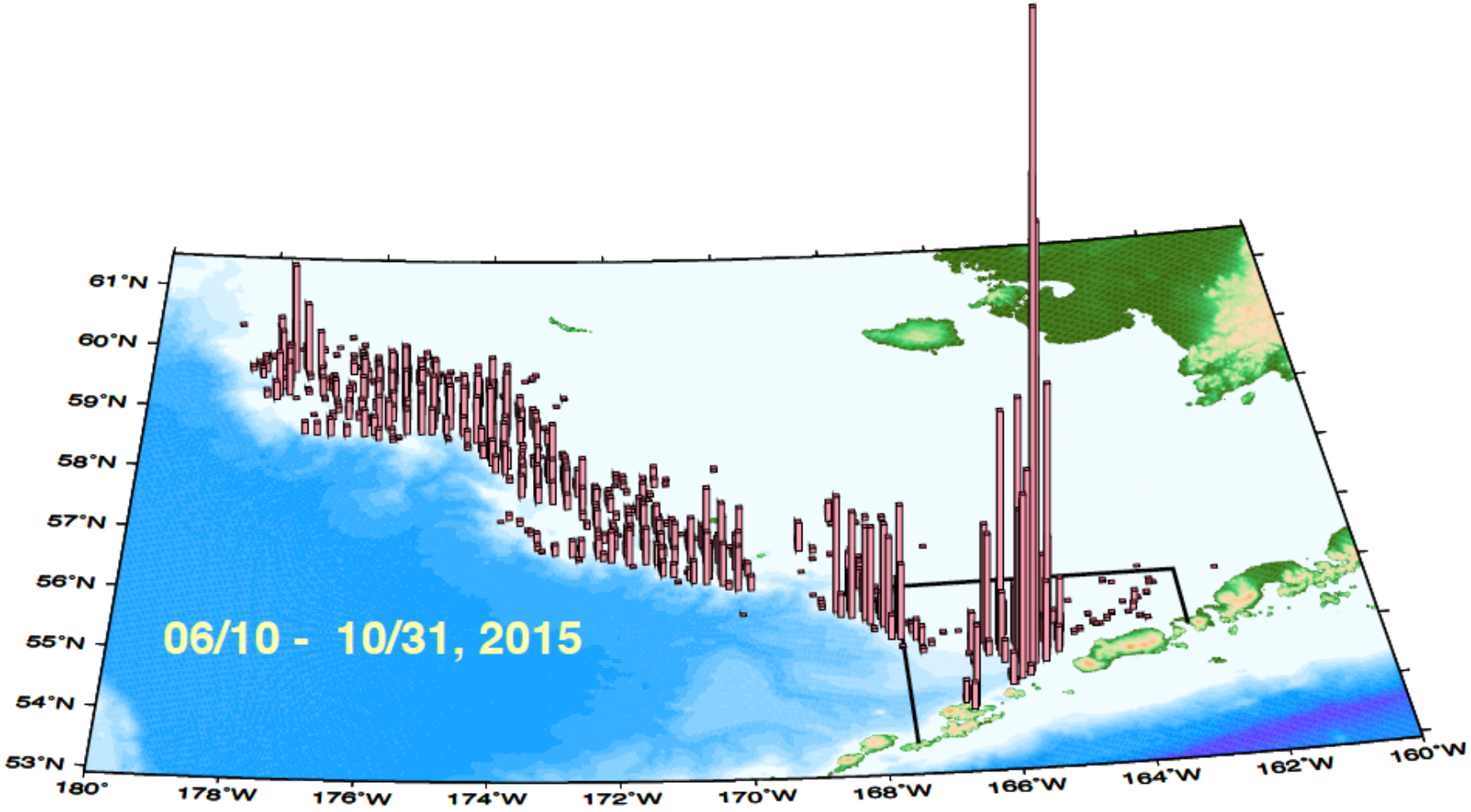


Table 1.7. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2014, as sampled by the NMFS observer program.

Length Frequency samples							
	A Season		B Season SE		B Season NW		
Year	Males	Females	Males	Females	Males	Females	Total
1977	26,411	25,923	4,301	4,511	29,075	31,219	121,440
1978	25,110	31,653	9,829	9,524	46,349	46,072	168,537
1979	59,782	62,512	3,461	3,113	62,298	61,402	252,568
1980	42,726	42,577	3,380	3,464	47,030	49,037	188,214
1981	64,718	57,936	2,401	2,147	53,161	53,570	233,933
1982	74,172	70,073	16,265	14,885	181,606	163,272	520,273
1983	94,118	90,778	16,604	16,826	193,031	174,589	585,946
1984	158,329	161,876	106,654	105,234	243,877	217,362	993,332
1985	119,384	109,230	96,684	97,841	284,850	256,091	964,080
1986	186,505	189,497	135,444	123,413	164,546	131,322	930,727
1987	373,163	399,072	14,170	21,162	24,038	22,117	853,722
1991	160,491	148,236	166,117	150,261	141,085	139,852	906,042
1992	158,405	153,866	163,045	164,227	101,036	102,667	843,244
1993	143,296	133,711	148,299	140,402	27,262	28,522	621,490
1994	139,332	147,204	159,341	153,526	28,015	27,953	655,370
1995	131,287	128,389	179,312	154,520	16,170	16,356	626,032
1996	149,111	140,981	200,482	156,804	18,165	18,348	683,890
1997	124,953	104,115	116,448	107,630	60,192	53,191	566,527
1998	136,605	110,620	208,659	178,012	32,819	40,307	707,019
1999	36,258	32,630	38,840	35,695	16,282	18,339	178,044
2000	64,575	58,162	63,832	41,120	40,868	39,134	307,689
2001	79,333	75,633	54,119	51,268	44,295	45,836	350,483
2002	71,776	69,743	65,432	64,373	37,701	39,322	348,347
2003	74,995	77,612	49,469	53,053	51,799	53,463	360,390
2004	75,426	76,018	63,204	62,005	47,289	44,246	368,188
2005	76,627	69,543	43,205	33,886	68,878	63,088	355,225
2006	72,353	63,108	28,799	22,363	75,180	65,209	327,010
2007	62,827	60,522	32,945	25,518	75,128	69,116	326,054
2008	46,125	51,027	20,493	23,503	61,149	64,598	266,894
2009	46,051	44,080	19,877	18,579	50,451	53,344	232,379
2010	39,495	41,054	19,194	20,591	40,449	41,323	202,106
2011	58,822	62,617	60,254	65,057	51,137	48,084	345,971
2012	53,641	57,966	45,044	46,940	50,167	53,224	306,982
2013	52,303	62,336	37,434	44,709	49,484	49,903	296,168
2014	55,954	58,097	46,568	51,950	46,643	46,202	305,414

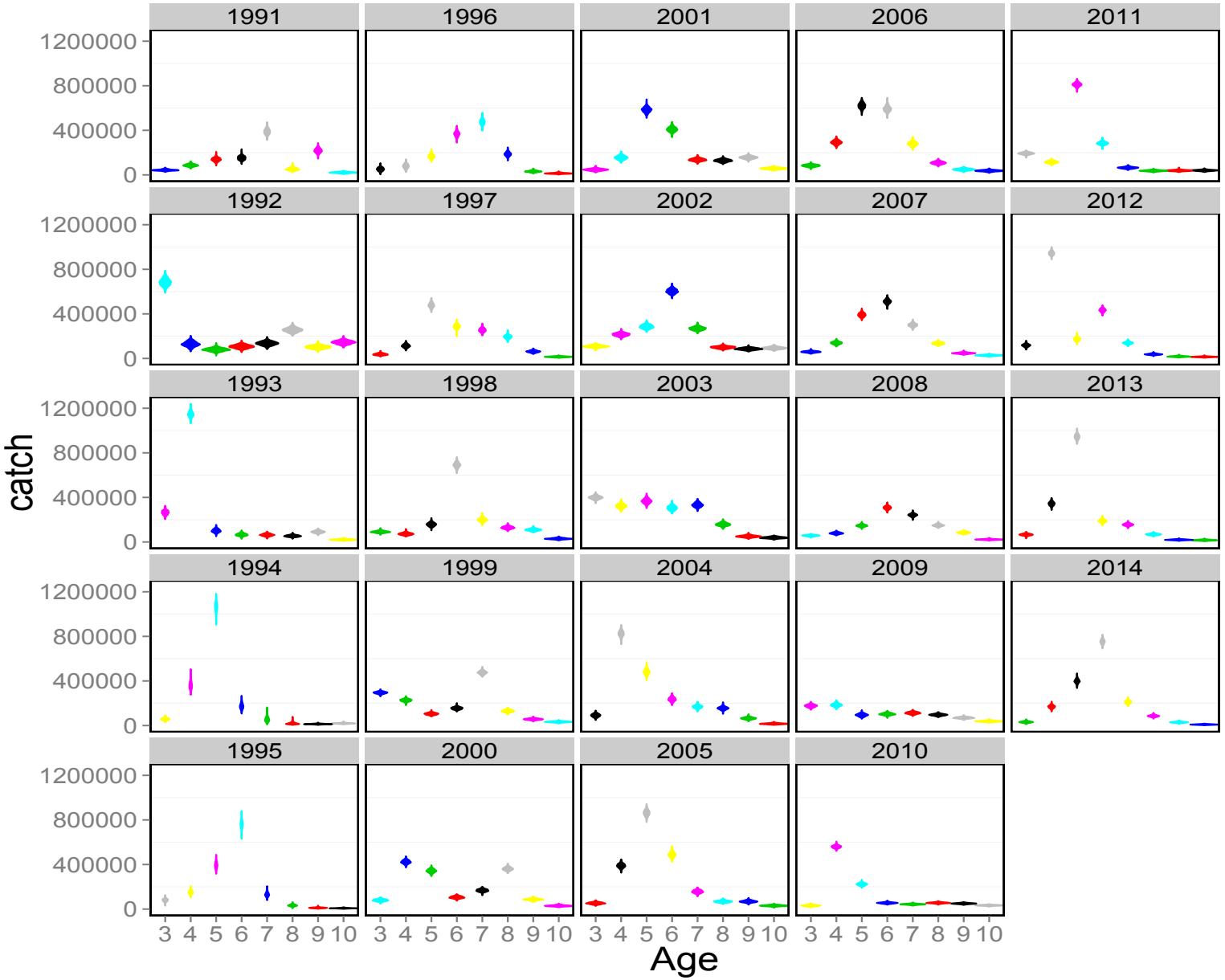
Fishery Ages

Table 1.8. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2014, as sampled by the NMFS observer program.

	Number of samples aged						
	A Season		B Season SE		B Season NW		
	Males	Females	Males	Females	Males	Females	Total
1977	1,229	1,344	137	166	1,415	1,613	5,904
1978	1,992	2,686	407	514	2,188	2,611	10,398
1979	2,647	3,088	152	209	1,464	1,561	9,121
1980	1,854	2,158	93	138	606	675	5,524
1981	1,819	2,042	51	52	1,620	1,807	7,391
1982	2,030	2,210	181	176	2,865	3,062	10,524
1983	1,200	1,200	144	122	3,249	3,420	9,335
1984	980	1,046	117	136	1,272	1,379	4,930
1985	520	499	46	55	426	488	2,034
1986	689	794	518	501	286	286	3,074
1987	1,351	1,466	25	33	72	63	3,010
1991	420	423	272	265	320	341	2,041
1992	392	392	371	386	178	177	1,896
1993	444	473	503	493	124	122	2,159
1994	201	202	570	573	131	141	1,818
1995	298	316	436	417	123	131	1,721
1996	468	449	442	433	1	1	1,794
1997	433	436	284	311	326	326	2,116
1998	592	659	307	307	216	232	2,313
1999	540	500	730	727	306	298	3,100
2000	666	626	843	584	253	293	3,265
2001	598	560	724	688	178	205	2,951
2002	651	670	834	886	201	247	3,489
2003	583	644	652	680	260	274	3,092
2004	560	547	599	697	244	221	2,867
2005	611	597	613	489	419	421	3,149
2006	608	599	590	457	397	398	3,048
2007	639	627	586	482	583	570	3,485
2008	492	491	313	356	541	647	2,838
2009	488	416	285	325	400	434	2,346
2010	624	545	504	419	465	414	2,971
2011	581	808	579	659	404	396	3,427
2012	517	571	480	533	485	579	3,165
2013	703	666	517	402	568	526	3,381
2014	609	629	475	553	413	407	

Fishery age data, EBS pollock

- Bootstrap distribution of catch-at-age from NMFS AFSC observer program
- Two-stage re-sampling stratified by 2 seasons and 2 areas
  - Samples hauls with replacement
  - Within those hauls samples lengths and ages
  - Calculate total LF (expanded by strata catches)
  - Creates sex-stratum specific ALK applied to those LFs
  - Summed for annual catch-at-age



Correlation from bootstrapping…

Age

2	3	4	5	6	7	8	9	10	11	12	13	14	15
2%	5%	7%	13%	26%	21%	13%	7%	2%	2%	1%	1%	0%	1%
	-0.36	0.05	0.03	0.02	-0.06	0.00	0.01	0.01	0.00	-0.01	-0.03	-0.03	-0.01
		-0.37	-0.04	-0.09	0.05	0.05	0.04	-0.03	0.02	-0.03	0.02	0.00	-0.03
			-0.32	-0.08	-0.05	0.01	-0.09	0.03	-0.03	0.02	-0.02	-0.02	0.01
				-0.35	-0.18	-0.07	-0.06	0.00	-0.05	0.01	0.02	-0.01	0.01
					-0.37	-0.27	-0.10	-0.06	-0.03	0.01	-0.01	0.02	0.00
						-0.28	-0.17	-0.07	-0.06	-0.06	0.00	0.01	-0.04
							-0.17	-0.07	-0.02	-0.10	-0.12	-0.08	0.00
								-0.07	-0.05	-0.10	-0.10	-0.02	-0.10
									-0.02	-0.12	0.00	0.00	-0.01
										-0.10	-0.08	-0.08	-0.09
											-0.12	-0.03	-0.01
												-0.08	-0.19
													0.00

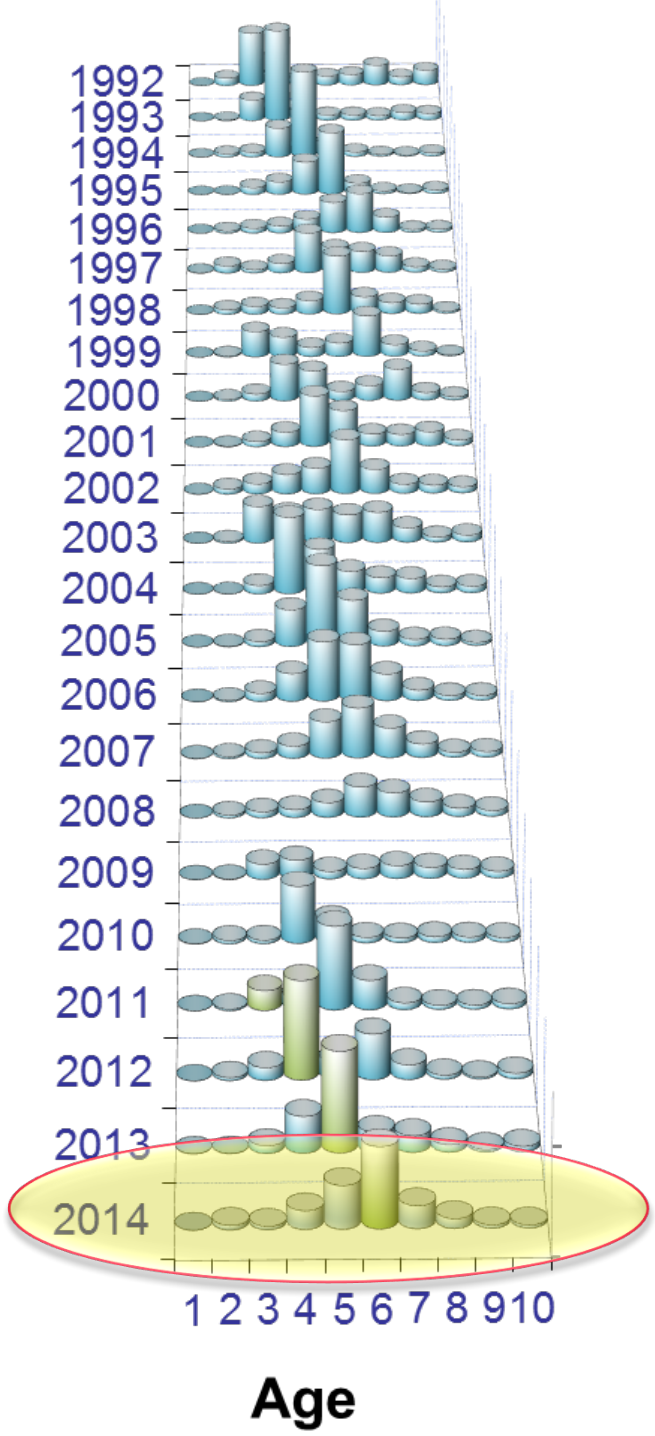
Bootstrap

	-0.03	-0.04	-0.06	-0.09	-0.08	-0.06	-0.04	-0.02	-0.02	-0.02	-0.01	-0.01	-0.02
		-0.06	-0.09	-0.14	-0.12	-0.09	-0.06	-0.03	-0.03	-0.02	-0.02	-0.01	-0.02
			-0.10	-0.16	-0.14	-0.10	-0.07	-0.04	-0.03	-0.03	-0.02	-0.01	-0.03
				-0.23	-0.19	-0.15	-0.11	-0.05	-0.05	-0.04	-0.03	-0.02	-0.04
					-0.30	-0.23	-0.17	-0.08	-0.07	-0.06	-0.05	-0.03	-0.06
						-0.20	-0.14	-0.07	-0.06	-0.06	-0.04	-0.02	-0.05
							-0.11	-0.05	-0.05	-0.04	-0.03	-0.02	-0.04
								-0.04	-0.03	-0.03	-0.02	-0.01	-0.03
									-0.02	-0.02	-0.01	-0.01	-0.01
										-0.01	-0.01	-0.01	-0.01
											-0.01	-0.01	-0.01
												0.00	-0.01
													0.00

Expected from multinomial

Eastern Bering Sea
Pollock

Fishery age composition



Growth variability

Observed Data

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.28	0.48	0.61	0.73	0.85	0.89	1.01	1.14	1.13	1.25	1.23	1.30	1.24
1992	0.40	0.47	0.65	0.71	0.81	0.98	1.03	1.20	1.24	1.28	1.21	1.37	1.45
1993	0.49	0.61	0.66	0.77	0.93	1.05	1.20	1.23	1.41	1.54	1.65	1.67	1.56
1994	0.40	0.65	0.73	0.75	0.73	1.05	1.38	1.32	1.32	1.39	1.39	1.30	1.35
1995	0.38	0.50	0.73	0.84	0.85	0.98	1.23	1.31	1.41	1.46	1.40	1.12	1.34
1996	0.33	0.44	0.68	0.79	0.95	0.95	1.02	1.10	1.40	1.49	1.51	1.73	1.52
1997	0.33	0.46	0.55	0.74	0.89	1.08	1.10	1.24	1.35	1.47	1.63	1.40	1.35
1998	0.36	0.58	0.63	0.62	0.78	1.03	1.17	1.25	1.32	1.42	1.44	1.54	1.55
1999	0.40	0.50	0.64	0.70	0.79	0.89	1.03	1.26	1.26	1.40	1.01	0.56	1.24
2000	0.35	0.53	0.63	0.73	0.78	0.81	0.97	1.01	1.25	1.29	1.11	1.21	1.46
2001	0.33	0.50	0.66	0.79	0.96	0.99	1.06	1.14	1.32	1.45	1.53	1.48	1.46
2002	0.38	0.51	0.67	0.80	0.91	1.03	1.11	1.10	1.28	1.45	1.59	1.33	1.63
2003	0.49	0.55	0.65	0.77	0.86	0.95	1.08	1.21	1.21	1.20	1.38	1.27	1.70
2004	0.40	0.58	0.64	0.76	0.89	0.93	1.03	1.18	1.13	1.17	1.33	1.28	1.22
2005	0.35	0.51	0.64	0.74	0.88	0.95	1.07	1.09	1.23	1.28	1.26	1.07	1.40
2006	0.31	0.45	0.60	0.75	0.86	0.96	1.06	1.12	1.22	1.24	1.30	1.39	1.42
2007	0.34	0.51	0.64	0.78	0.96	1.10	1.19	1.27	1.31	1.47	1.44	1.73	1.51
2008	0.33	0.52	0.65	0.77	0.90	1.04	1.11	1.22	1.30	1.41	1.49	1.50	1.50
2009	0.35	0.55	0.69	0.89	1.02	1.15	1.41	1.49	1.63	1.64	1.82	2.18	2.30
2010	0.38	0.49	0.67	0.92	1.11	1.26	1.34	1.60	1.61	1.85	1.94	2.06	2.21
2011	0.29	0.51	0.66	0.81	0.97	1.22	1.34	1.50	1.57	1.62	2.12	1.74	2.26
2012	0.27	0.41	0.64	0.82	0.97	1.18	1.31	1.53	1.61	1.65	1.73	2.03	2.12
2013	0.29	0.44	0.57	0.78	1.12	1.28	1.43	1.70	1.85	1.82	1.94	2.12	2.09
2014	0.32	0.46	0.62	0.75	0.89	1.15	1.32	1.38	1.68	1.80	1.75	1.68	2.21
2015													
2016													
2017													

??

Growth variability

Cohort- and year effects…

Model Estimates

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.35	0.46	0.60	0.72	0.84	0.89	1.02	1.12	1.13	1.17	1.25	1.35	1.26
1992	0.40	0.48	0.59	0.73	0.85	0.97	1.03	1.15	1.22	1.23	1.25	1.35	1.41
1993	0.46	0.61	0.68	0.81	0.95	1.09	1.25	1.29	1.39	1.48	1.47	1.51	1.58
1994	0.40	0.59	0.73	0.78	0.88	1.03	1.18	1.33	1.32	1.43	1.49	1.50	1.49
1995	0.35	0.51	0.72	0.85	0.86	0.97	1.13	1.26	1.37	1.36	1.45	1.53	1.49
1996	0.38	0.46	0.62	0.82	0.94	0.94	1.06	1.20	1.30	1.41	1.38	1.49	1.52
1997	0.40	0.49	0.55	0.72	0.92	1.03	1.03	1.14	1.25	1.36	1.44	1.43	1.49
1998	0.38	0.51	0.59	0.64	0.80	1.01	1.13	1.11	1.17	1.29	1.37	1.48	1.42
1999	0.39	0.51	0.64	0.71	0.73	0.90	1.13	1.25	1.17	1.25	1.35	1.45	1.52
2000	0.38	0.51	0.62	0.75	0.79	0.81	1.00	1.23	1.30	1.23	1.29	1.41	1.47
2001	0.40	0.53	0.67	0.79	0.91	0.95	0.97	1.17	1.39	1.48	1.36	1.44	1.53
2002	0.42	0.53	0.66	0.80	0.89	1.02	1.06	1.06	1.23	1.47	1.53	1.44	1.47
2003	0.44	0.55	0.66	0.79	0.91	1.01	1.15	1.17	1.13	1.32	1.53	1.62	1.47
2004	0.40	0.56	0.66	0.76	0.86	0.98	1.09	1.21	1.19	1.16	1.32	1.56	1.59
2005	0.36	0.49	0.66	0.73	0.81	0.91	1.04	1.12	1.20	1.19	1.13	1.31	1.49
2006	0.35	0.47	0.60	0.77	0.82	0.89	1.00	1.12	1.16	1.26	1.22	1.17	1.31
2007	0.37	0.52	0.64	0.79	0.96	1.02	1.11	1.22	1.31	1.37	1.45	1.42	1.32
2008	0.34	0.49	0.64	0.77	0.90	1.09	1.15	1.22	1.30	1.40	1.44	1.54	1.46
2009	0.38	0.53	0.70	0.89	1.01	1.18	1.43	1.47	1.51	1.61	1.70	1.76	1.83
2010	0.33	0.50	0.66	0.84	1.01	1.14	1.33	1.57	1.56	1.61	1.67	1.79	1.80
2011	0.30	0.47	0.65	0.82	1.00	1.20	1.35	1.54	1.75	1.75	1.76	1.86	1.93
2012	0.30	0.41	0.59	0.80	0.96	1.16	1.39	1.52	1.67	1.91	1.87	1.91	1.95
2013	0.31	0.44	0.57	0.78	1.00	1.19	1.44	1.68	1.78	1.97	2.20	2.18	2.16
2014	0.33	0.45	0.60	0.74	0.97	1.23	1.47	1.73	1.94	2.07	2.23	2.53	2.43
2015	0.36	0.35	0.44	0.57	0.67	0.87	1.11	1.28	1.46	1.65	1.72	1.88	2.06
2016	0.36	0.49	0.44	0.53	0.66	0.76	0.99	1.23	1.37	1.57	1.73	1.83	1.94
2017	0.36	0.49	0.61	0.53	0.61	0.74	0.86	1.10	1.31	1.47	1.65	1.85	1.89

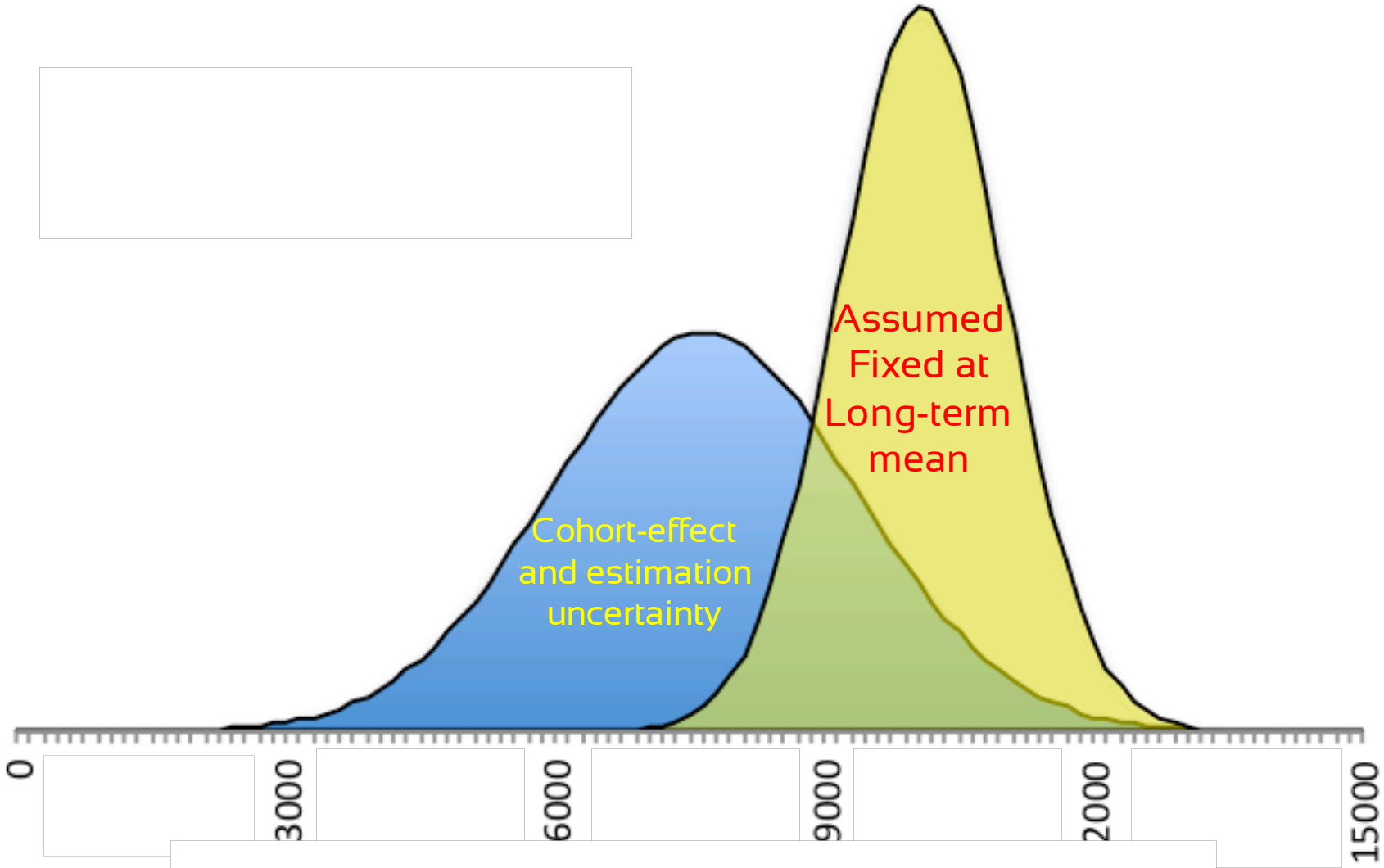
Why do we care?

ABC specifications require "reliable" estimates of F_{msy} *and* the uncertainty of the estimate...

What affects productivity estimates?

- Stock-recruit relationship
- Fishery selectivity
- Natural mortality
- Body mass-at-age

Impact on biomass estimate



Biomass (thousands of tons)

Mean weight-at-age

$$\hat{w}_{at} = \mu_a e^{\varepsilon_t^y + \varepsilon_a^c}, \ \varepsilon_t^y \sim N\left(0, \sigma_y^2\right), \ \varepsilon_a^c \sim N\left(0, \sigma_c^2\right)$$

ε_a^c Value for each cohort, 1991-2017 (13+26 = 39)

ε_t^y Value for each "year" effect, 1991-2017 (27 years)

Growth variability

Observed Data

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.28	0.48	0.61	0.73	0.85	0.89	1.01	1.14	1.13	1.25	1.23	1.30	1.24
1992	0.40	0.47	0.65	0.71	0.81	0.98	1.03	1.20	1.24	1.28	1.21	1.37	1.45
1993	0.49	0.61	0.66	0.77	0.93	1.05	1.20	1.23	1.41	1.54	1.65	1.67	1.56
1994	0.40	0.65	0.73	0.75	0.73	1.05	1.38	1.32	1.32	1.39	1.39	1.30	1.35
1995	0.38	0.50	0.73	0.84	0.85	0.98	1.23	1.31	1.41	1.46	1.40	1.12	1.34
1996	0.33	0.44	0.68	0.79	0.95	0.95	1.02	1.10	1.40	1.49	1.51	1.73	1.52
1997	0.33	0.46	0.55	0.74	0.89	1.08	1.10	1.24	1.35	1.47	1.63	1.40	1.35
1998	0.36	0.58	0.63	0.62	0.78	1.03	1.17	1.25	1.32	1.42	1.44	1.54	1.55
1999	0.40	0.50	0.64	0.70	0.73	0.89	1.03	1.26	1.26	1.40	1.01	0.56	1.24
2000	0.35	0.53	0.63	0.73	0.78	0.81	0.97	1.01	1.25	1.29	1.11	1.21	1.46
2001	0.33	0.50	0.66	0.79	0.96	0.99	1.06	1.14	1.32	1.45	1.56	1.48	1.46
2002	0.38	0.51	0.67	0.80	0.91	1.03	1.11	1.10	1.28	1.45	1.59	1.33	1.63
2003	0.49	0.55	0.65	0.77	0.86	0.95	1.08	1.21	1.21	1.20	1.38	1.27	1.70
2004	0.40	0.58	0.64	0.76	0.89	0.93	1.03	1.18	1.13	1.17	1.33	1.28	1.22
2005	0.35	0.51	0.64	0.74	0.88	0.95	1.07	1.09	1.23	1.28	1.26	1.07	1.40
2006	0.31	0.45	0.60	0.75	0.86	0.96	1.06	1.12	1.22	1.24	1.30	1.39	1.42
2007	0.34	0.51	0.64	0.78	0.96	1.10	1.19	1.27	1.31	1.47	1.44	1.73	1.51
2008	0.33	0.52	0.65	0.77	0.90	1.04	1.11	1.22	1.30	1.41	1.49	1.50	1.50
2009	0.35	0.55	0.69	0.89	1.02	1.15	1.41	1.49	1.63	1.64	1.82	2.18	2.30
2010	0.38	0.49	0.67	0.92	1.11	1.26	1.34	1.60	1.61	1.85	1.94	2.06	2.21
2011	0.29	0.51	0.66	0.81	0.97	1.22	1.34	1.50	1.57	1.62	2.12	1.74	2.26
2012	0.27	0.41	0.64	0.82	0.97	1.18	1.31	1.53	1.61	1.65	1.73	2.03	2.12
2013	0.29	0.44	0.57	0.78	1.12	1.28	1.43	1.70	1.85	1.82	1.94	2.12	2.09
2014	0.32	0.46	0.62	0.75	0.89	1.15	1.32	1.38	1.68	1.80	1.75	1.68	2.21
2015													
2016													
2017													

Growth variability

Cohort- and year effects…

Model Estimates

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.35	0.46	0.60	0.72	0.84	0.89	1.02	1.12	1.13	1.17	1.25	1.35	1.26
1992	0.40	0.48	0.59	0.73	0.85	0.97	1.03	1.15	1.22	1.23	1.25	1.35	1.41
1993	0.46	0.61	0.68	0.81	0.95	1.09	1.25	1.29	1.39	1.48	1.47	1.51	1.58
1994	0.40	0.59	0.73	0.78	0.88	1.03	1.18	1.33	1.32	1.43	1.49	1.50	1.49
1995	0.35	0.51	0.72	0.85	0.86	0.97	1.13	1.26	1.37	1.36	1.45	1.53	1.49
1996	0.38	0.46	0.62	0.82	0.94	0.94	1.06	1.20	1.30	1.41	1.38	1.49	1.52
1997	0.40	0.49	0.55	0.72	0.92	1.03	1.03	1.14	1.25	1.36	1.44	1.43	1.49
1998	0.38	0.51	0.59	0.64	0.80	1.01	1.13	1.11	1.17	1.29	1.37	1.48	1.42
1999	0.39	0.51	0.64	0.71	0.73	0.90	1.13	1.25	1.17	1.25	1.35	1.45	1.52
2000	0.38	0.51	0.62	0.75	0.79	0.81	1.00	1.23	1.30	1.23	1.29	1.41	1.47
2001	0.40	0.53	0.67	0.79	0.91	0.95	0.97	1.17	1.39	1.48	1.36	1.44	1.53
2002	0.42	0.53	0.66	0.80	0.89	1.02	1.06	1.06	1.23	1.47	1.53	1.44	1.47
2003	0.44	0.55	0.66	0.79	0.91	1.01	1.15	1.17	1.13	1.32	1.53	1.62	1.47
2004	0.40	0.56	0.66	0.76	0.86	0.98	1.09	1.21	1.19	1.16	1.32	1.56	1.59
2005	0.36	0.49	0.66	0.73	0.81	0.91	1.04	1.12	1.20	1.19	1.13	1.31	1.49
2006	0.35	0.47	0.60	0.77	0.82	0.89	1.00	1.12	1.16	1.26	1.22	1.17	1.31
2007	0.37	0.52	0.64	0.79	0.96	1.02	1.11	1.22	1.31	1.37	1.45	1.42	1.32
2008	0.34	0.49	0.64	0.77	0.90	1.09	1.15	1.22	1.30	1.40	1.44	1.54	1.46
2009	0.38	0.53	0.70	0.89	1.01	1.18	1.43	1.47	1.51	1.61	1.70	1.76	1.83
2010	0.33	0.50	0.66	0.84	1.01	1.14	1.33	1.57	1.56	1.61	1.67	1.79	1.80
2011	0.30	0.47	0.65	0.82	1.00	1.20	1.35	1.54	1.75	1.75	1.76	1.86	1.93
2012	0.30	0.41	0.59	0.80	0.96	1.16	1.39	1.52	1.67	1.91	1.87	1.91	1.95
2013	0.31	0.44	0.57	0.78	1.00	1.19	1.44	1.68	1.78	1.97	2.20	2.18	2.16
2014	0.33	0.45	0.60	0.74	0.97	1.23	1.47	1.73	1.94	2.07	2.23	2.53	2.43
2015	0.36	0.35	0.44	0.57	0.67	0.87	1.11	1.28	1.46	1.65	1.72	1.88	2.06
2016	0.36	0.49	0.44	0.53	0.66	0.76	0.99	1.23	1.37	1.57	1.73	1.83	1.94
2017	0.36	0.49	0.61	0.53	0.61	0.74	0.86	1.10	1.31	1.47	1.65	1.85	1.89

Estimating fishery wt-at-age variability

Procedure:

- Use separate code for a random effects model to estimate process error terms (cohort and year effects)
- Use those variances as for penalty terms in full assessment model
- Values same and variances reasonable

Observed Data

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.28	0.48	0.61	0.73	0.85	0.89	1.01	1.14	1.13	1.25	1.23	1.30	1.24
1992	0.40	0.47	0.65	0.71	0.81	0.98	1.03	1.20	1.24	1.28	1.21	1.37	1.45
1993	0.49	0.61	0.66	0.77	0.93	1.05	1.20	1.23	1.41	1.54	1.65	1.67	1.56
1994	0.40	0.65	0.73	0.75	0.73	1.05	1.38	1.32	1.32	1.39	1.39	1.30	1.35
1995	0.38	0.50	0.73	0.84	0.85	0.98	1.23	1.31	1.41	1.46	1.40	1.12	1.34
1996	0.33	0.44	0.68	0.79	0.95	0.95	1.02	1.10	1.40	1.49	1.51	1.73	1.52
1997	0.33	0.46	0.55	0.74	0.89	1.08	1.10	1.24	1.35	1.47	1.63	1.40	1.35
1998	0.36	0.58	0.63	0.62	0.78	1.03	1.17	1.25	1.32	1.42	1.44	1.54	1.55
1999	0.40	0.50	0.64	0.70	0.73	0.89	1.03	1.26	1.26	1.40	1.01	0.56	1.24
2000	0.35	0.53	0.63	0.73	0.78	0.81	0.97	1.01	1.25	1.29	1.11	1.21	1.46
2001	0.33	0.50	0.66	0.79	0.96	0.99	1.06	1.14	1.32	1.45	1.56	1.48	1.46
2002	0.38	0.51	0.67	0.80	0.91	1.03	1.11	1.10	1.28	1.45	1.59	1.33	1.63
2003	0.49	0.55	0.65	0.77	0.86	0.95	1.08	1.21	1.21	1.20	1.38	1.27	1.70
2004	0.40	0.58	0.64	0.76	0.89	0.93	1.03	1.18	1.13	1.17	1.33	1.28	1.22
2005	0.35	0.51	0.64	0.74	0.88	0.95	1.07	1.09	1.23	1.28	1.26	1.07	1.40
2006	0.31	0.45	0.60	0.75	0.86	0.96	1.06	1.12	1.22	1.24	1.30	1.39	1.42
2007	0.34	0.51	0.64	0.78	0.96	1.10	1.19	1.27	1.31	1.47	1.44	1.73	1.51
2008	0.33	0.52	0.65	0.77	0.90	1.04	1.11	1.22	1.30	1.41	1.49	1.50	1.50
2009	0.35	0.55	0.69	0.89	1.02	1.15	1.41	1.49	1.63	1.64	1.82	2.18	2.30
2010	0.38	0.49	0.67	0.92	1.11	1.26	1.34	1.60	1.61	1.85	1.94	2.06	2.21
2011	0.29	0.51	0.66	0.81	0.97	1.22	1.34	1.50	1.57	1.62	2.12	1.74	2.26
2012	0.27	0.41	0.64	0.82	0.97	1.18	1.31	1.53	1.61	1.65	1.73	2.03	2.12
2013	0.29	0.44	0.57	0.78	1.12	1.28	1.43	1.70	1.85	1.82	1.94	2.12	2.09
2014	0.32	0.46	0.62	0.75	0.89	1.15	1.32	1.38	1.68	1.80	1.75	1.68	2.21
2015	?	?	?	?	?	?	?	?	?	?	?	?	?
2016	?	?	?	?	?	?	?	?	?	?	?	?	?
2017	?	?	?	?	?	?	?	?	?	?	?	?	?

Model Estimates

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.35	0.46	0.60	0.72	0.84	0.89	1.02	1.12	1.13	1.17	1.25	1.35	1.26
1992	0.40	0.48	0.59	0.73	0.85	0.97	1.03	1.15	1.22	1.23	1.25	1.35	1.41
1993	0.46	0.61	0.68	0.81	0.95	1.09	1.25	1.29	1.39	1.48	1.47	1.51	1.58
1994	0.40	0.59	0.73	0.78	0.88	1.03	1.18	1.33	1.32	1.43	1.49	1.50	1.49
1995	0.35	0.51	0.72	0.85	0.86	0.97	1.13	1.26	1.37	1.36	1.45	1.53	1.49
1996	0.38	0.46	0.62	0.82	0.94	0.94	1.06	1.20	1.30	1.41	1.38	1.49	1.52
1997	0.40	0.49	0.55	0.72	0.92	1.03	1.03	1.14	1.25	1.36	1.44	1.43	1.49
1998	0.38	0.51	0.59	0.64	0.80	1.01	1.13	1.11	1.17	1.29	1.37	1.48	1.42
1999	0.39	0.51	0.64	0.71	0.73	0.90	1.13	1.25	1.17	1.25	1.35	1.45	1.52
2000	0.38	0.51	0.62	0.75	0.79	0.81	1.00	1.23	1.30	1.23	1.29	1.41	1.47
2001	0.40	0.53	0.67	0.79	0.91	0.95	0.97	1.17	1.39	1.48	1.36	1.44	1.53
2002	0.42	0.53	0.66	0.80	0.89	1.02	1.06	1.06	1.23	1.47	1.53	1.44	1.47
2003	0.44	0.55	0.66	0.79	0.91	1.01	1.15	1.17	1.13	1.32	1.53	1.62	1.47
2004	0.40	0.56	0.66	0.76	0.86	0.98	1.09	1.21	1.19	1.16	1.32	1.56	1.59
2005	0.36	0.49	0.66	0.73	0.81	0.91	1.04	1.12	1.20	1.19	1.13	1.31	1.49
2006	0.35	0.47	0.60	0.77	0.82	0.89	1.00	1.12	1.16	1.26	1.22	1.17	1.31
2007	0.37	0.52	0.64	0.79	0.96	1.02	1.11	1.22	1.31	1.37	1.45	1.42	1.32
2008	0.34	0.49	0.64	0.77	0.90	1.09	1.15	1.22	1.30	1.40	1.44	1.54	1.46
2009	0.38	0.53	0.70	0.89	1.01	1.18	1.43	1.47	1.51	1.61	1.70	1.76	1.83
2010	0.33	0.50	0.66	0.84	1.01	1.14	1.33	1.57	1.56	1.61	1.67	1.79	1.80
2011	0.30	0.47	0.65	0.82	1.00	1.20	1.35	1.54	1.75	1.75	1.76	1.86	1.93
2012	0.30	0.41	0.59	0.80	0.96	1.16	1.39	1.52	1.67	1.91	1.87	1.91	1.95
2013	0.31	0.44	0.57	0.78	1.00	1.19	1.44	1.68	1.78	1.97	2.20	2.18	2.16
2014	0.33	0.45	0.60	0.74	0.97	1.23	1.47	1.73	1.94	2.07	2.23	2.53	2.43
2015	0.36	0.35	0.44	0.57	0.67	0.87	1.11	1.28	1.46	1.65	1.72	1.88	2.06
2016	0.36	0.49	0.44	0.53	0.66	0.76	0.99	1.23	1.37	1.57	1.73	1.83	1.94
2017	0.36	0.49	0.61	0.53	0.61	0.74	0.86	1.10	1.31	1.47	1.65	1.85	1.89

CVs of Observed Data

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	2%	2%	2%	2%	1%	4%	2%	7%	3%	7%	4%	7%	5%
1992	1%	2%	3%	2%	2%	2%	4%	3%	4%	5%	14%	8%	9%
1993	1%	0%	2%	3%	3%	4%	3%	5%	6%	10%	11%	16%	12%
1994	3%	1%	1%	2%	5%	13%	7%	7%	6%	7%	8%	15%	8%
1995	2%	2%	1%	1%	2%	4%	7%	8%	7%	14%	8%	53%	9%
1996	2%	4%	2%	1%	1%	2%	4%	6%	18%	11%	9%	12%	13%
1997	3%	1%	1%	1%	2%	2%	4%	8%	14%	14%	23%	9%	9%
1998	2%	3%	2%	1%	2%	3%	2%	6%	11%	13%	18%	24%	22%
1999	0%	1%	1%	1%	1%	2%	3%	5%	15%	27%	43%	57%	27%
2000	1%	1%	1%	2%	1%	1%	3%	6%	6%	13%	52%	76%	70%
2001	2%	1%	1%	1%	3%	3%	2%	5%	7%	9%	13%	14%	47%
2002	1%	1%	1%	1%	1%	3%	3%	3%	6%	7%	11%	34%	35%
2003	1%	1%	1%	1%	1%	2%	4%	6%	5%	7%	14%	36%	22%
2004	2%	1%	1%	2%	2%	2%	3%	8%	6%	6%	14%	18%	11%
2005	2%	1%	0%	1%	2%	3%	3%	5%	8%	8%	25%	37%	28%
2006	1%	1%	1%	1%	1%	3%	4%	4%	9%	14%	12%	19%	11%
2007	1%	1%	1%	1%	1%	2%	4%	5%	7%	13%	14%	12%	10%
2008	1%	1%	1%	1%	1%	2%	3%	6%	7%	7%	8%	22%	8%
2009	1%	1%	3%	2%	2%	3%	4%	6%	10%	12%	9%	30%	16%
2010	2%	0%	1%	3%	3%	4%	4%	5%	7%	10%	15%	13%	11%
2011	1%	1%	0%	1%	3%	4%	5%	5%	6%	9%	29%	16%	21%
2012	1%	0%	1%	1%	2%	5%	8%	11%	9%	10%	13%	21%	45%
2013	1%	0%	0%	2%	3%	4%	8%	9%	10%	12%	13%	18%	16%
2014	2%	1%	1%	1%	2%	3%	6%	14%	16%	19%	16%	22%	17%
2015	?	?	?	?	?	?	?	?	?	?	?	?	?
2016	?	?	?	?	?	?	?	?	?	?	?	?	?
2017	?	?	?	?	?	?	?	?	?	?	?	?	?

Residuals & *CVs of projected estimates*

1.609	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	-3.2	0.8	0.7	0.3	0.5	0.0	-0.7	0.2	0.0	1.1	-0.3	-0.7	-0.4
1992	-1.1	-0.1	1.7	-0.6	-1.4	0.5	0.1	1.5	0.5	0.9	-0.3	0.2	0.4
1993	3.4	0.0	-1.1	-1.0	-0.5	-1.0	-1.8	-1.3	0.3	0.6	1.6	1.0	-0.2
1994	0.0	4.7	-0.7	-1.4	-2.9	0.2	2.7	-0.1	0.1	-0.7	-1.3	-1.3	-1.7
1995	1.1	-0.8	1.1	-0.5	-0.3	0.2	1.5	0.6	0.6	0.7	-0.6	-0.8	-1.7
1996	-2.1	-0.4	2.6	-2.4	0.9	0.5	-0.8	-1.7	0.6	0.7	1.4	2.0	0.0
1997	-2.4	-2.2	-0.2	1.4	-1.8	2.1	1.7	1.4	0.8	0.8	0.8	-0.3	-1.5
1998	-0.9	2.4	1.7	-2.7	-1.1	0.9	1.5	2.6	1.3	1.0	0.4	0.2	0.6
1999	2.7	-0.7	-0.1	-0.5	-0.4	-0.4	-3.1	0.2	0.6	0.5	-0.8	-1.6	-1.0
2000	-2.1	2.8	1.0	-1.2	-1.0	-0.6	-1.1	-3.8	-0.9	0.4	-0.3	-0.3	0.0
2001	-5.2	-2.3	-1.2	0.0	2.0	1.6	4.4	-0.7	-1.0	-0.3	1.5	0.3	-0.1
2002	-2.3	-2.8	0.7	-0.2	1.4	0.3	1.4	1.3	0.8	-0.3	0.6	-0.3	0.4
2003	8.4	-0.2	-1.4	-1.6	-4.1	-2.6	-1.8	0.7	1.5	-1.7	-1.0	-1.0	1.0
2004	0.4	3.5	-2.3	0.5	1.7	-3.2	-1.7	-0.5	-1.0	0.2	0.1	-1.6	-3.3
2005	-0.4	2.5	-3.9	0.7	4.3	1.5	1.0	-0.8	0.3	1.2	0.5	-0.6	-0.3
2006	-3.5	-2.9	0.7	-1.4	2.9	2.5	1.5	-0.1	0.7	-0.1	0.7	1.2	1.1
2007	-2.5	-1.0	0.1	-1.2	-0.4	3.5	2.0	1.0	0.1	0.8	-0.1	2.6	2.0
2008	-1.2	2.9	0.8	1.1	-0.3	-2.8	-1.8	0.0	0.1	0.1	0.7	-0.2	0.4
2009	-3.2	1.5	-0.6	0.1	0.4	-0.9	-0.4	0.3	1.2	0.3	1.4	1.4	3.0
2010	1.9	-3.5	0.9	2.4	3.3	3.0	0.3	0.5	0.7	2.5	1.8	2.0	3.5
2011	-2.6	3.3	2.0	-1.5	-1.0	0.5	-0.2	-0.7	-2.7	-1.4	1.3	-0.8	1.6
2012	-4.0	-1.5	3.2	3.2	0.7	0.3	-0.9	0.0	-0.6	-2.6	-1.1	0.6	0.4
2013	-2.1	-0.5	-0.6	0.2	4.5	2.4	-0.2	0.1	0.6	-1.1	-1.9	-0.3	-0.4
2014	-0.8	1.0	2.1	3.0	-4.8	-2.7	-2.7	-2.5	-1.6	-1.4	-3.0	-3.9	-1.3
2015	*19%*	*12%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*
2016	*19%*	*19%*	*12%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*
2017	*19%*	*19%*	*19%*	*12%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*

E. Bering Sea Pollock

Survey data

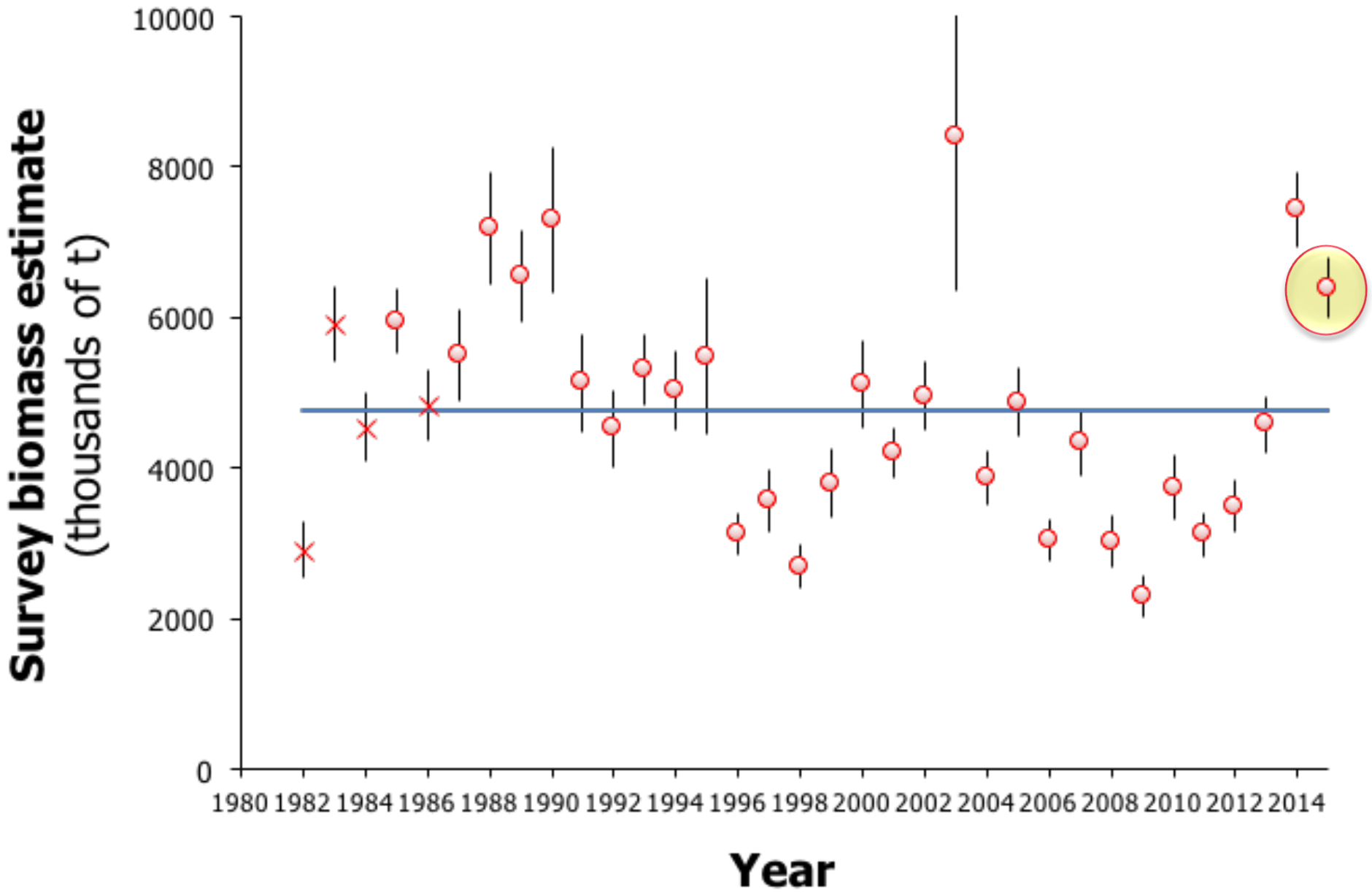
Types:

1. Bottom trawl
2. ~~Acoustic + mid-water trawl~~ To come in 2016
3. Opportunistic acoustic data collection

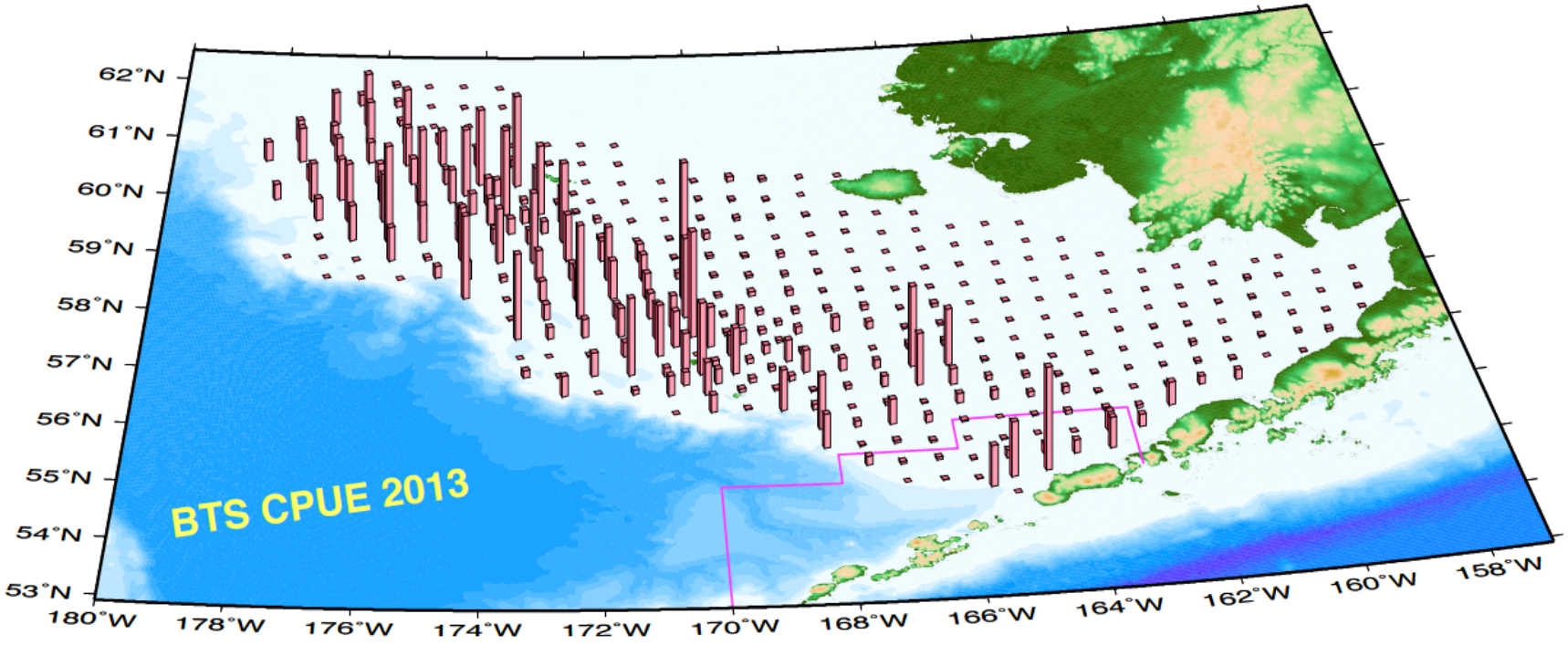
Collected onboard chartered bottom-trawl survey

Bottom-trawl survey

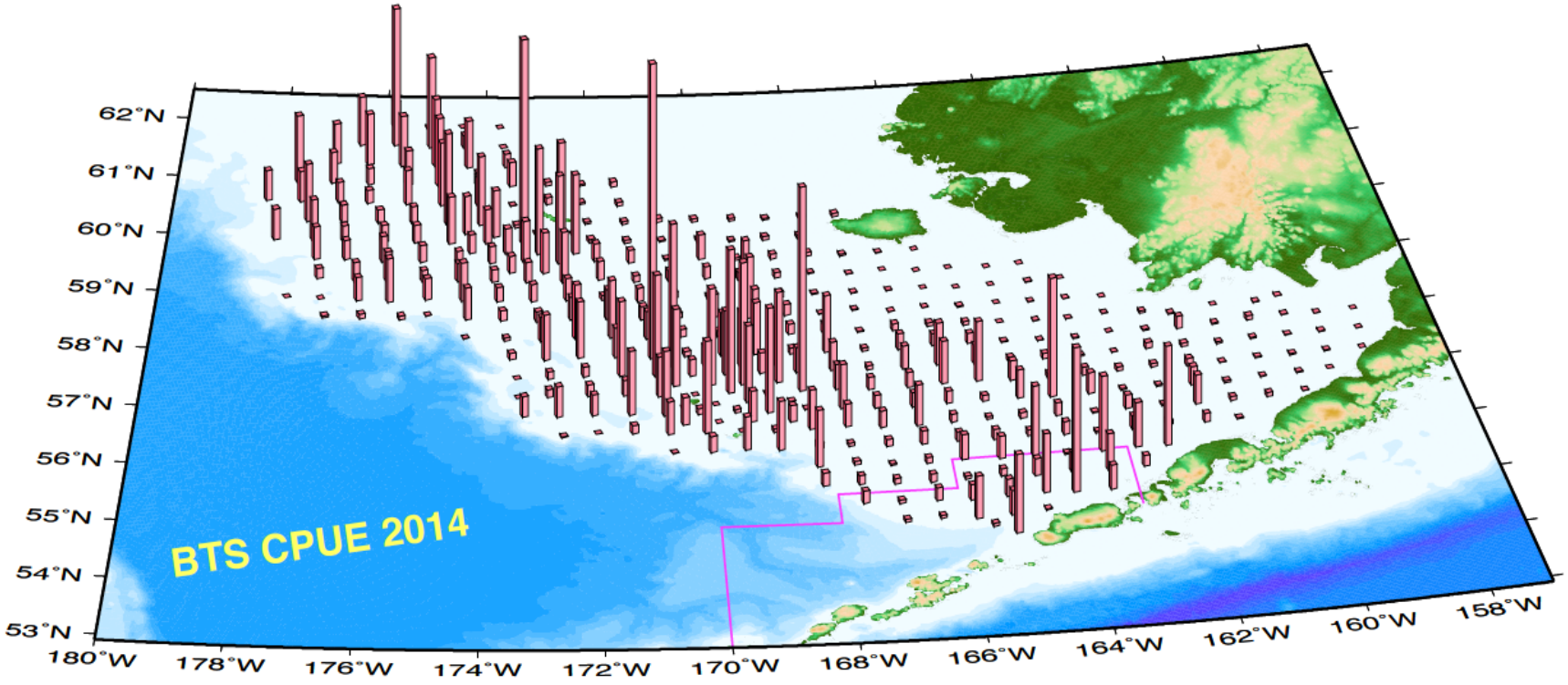
Pollock survey biomass trend



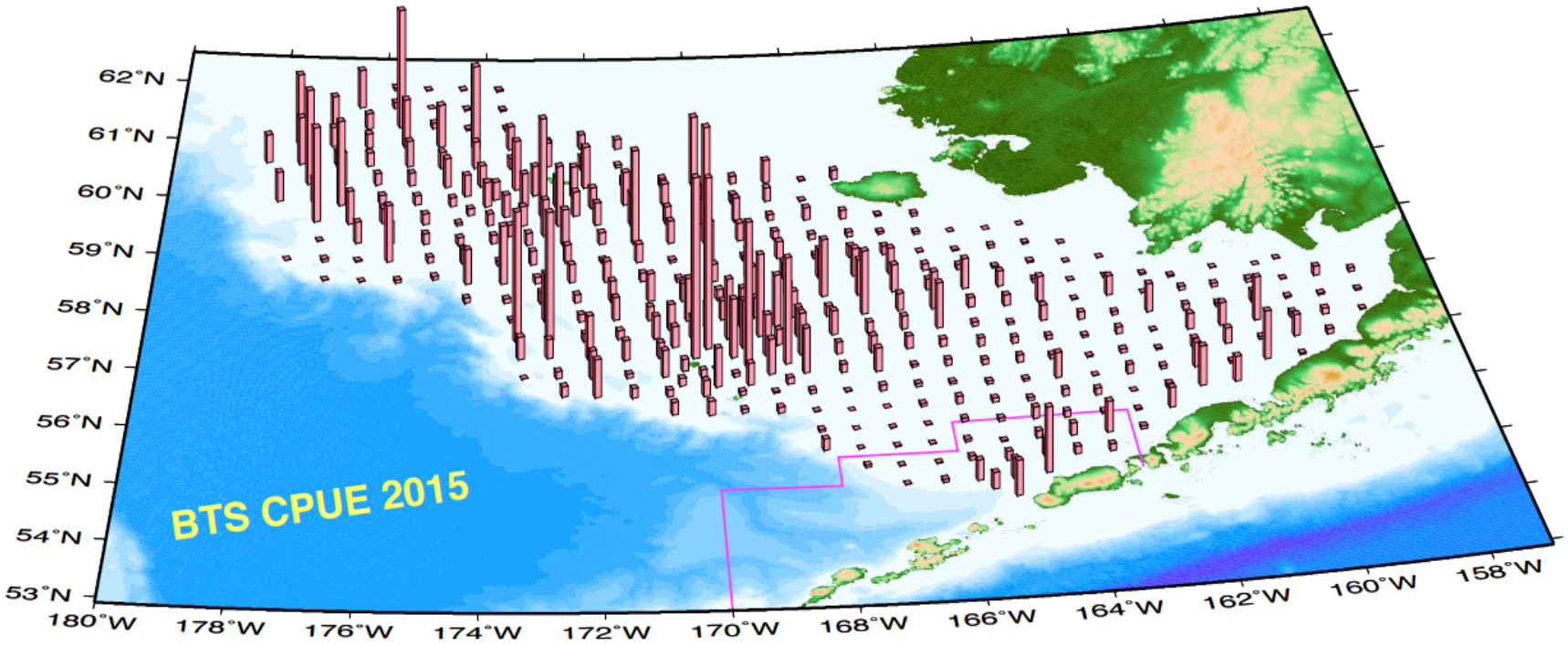
2013 pollock survey—4.6 million t



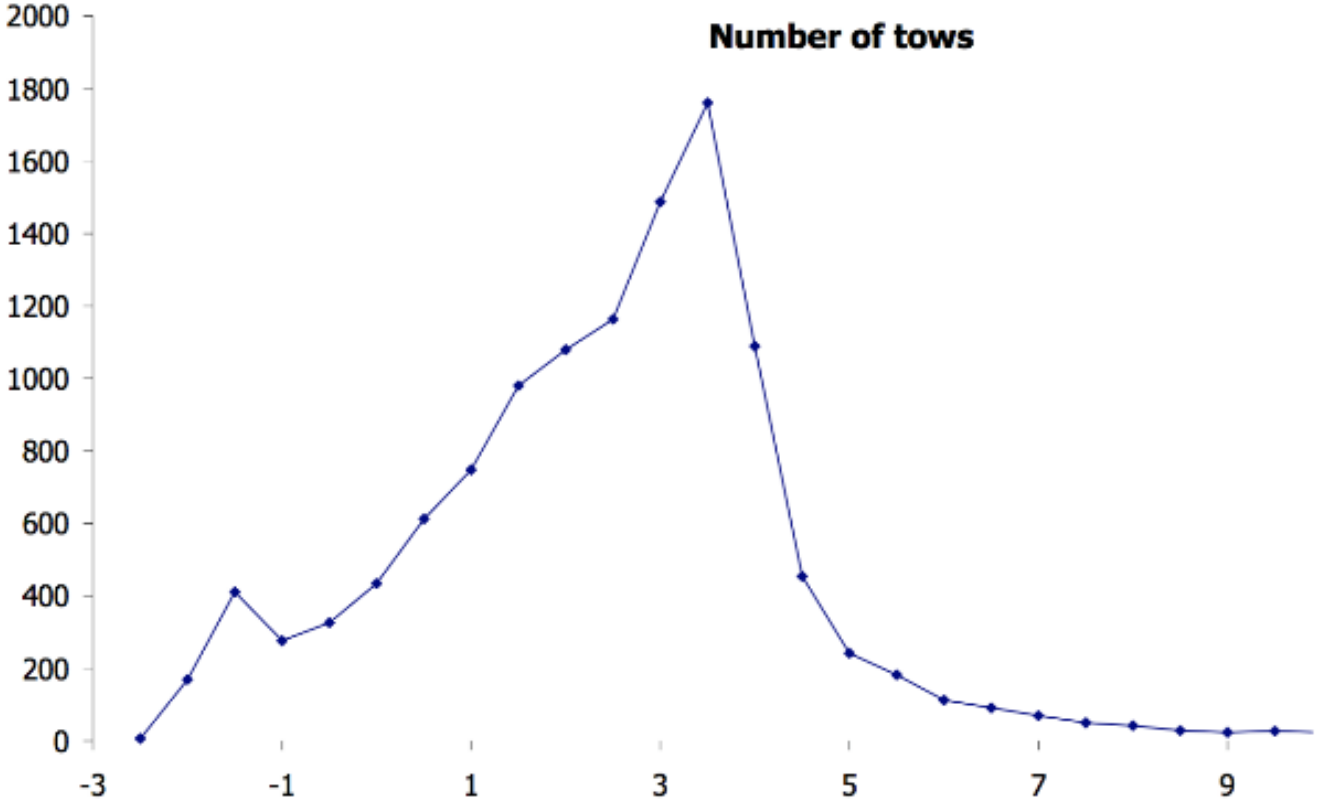
2014 pollock survey—7.4 million t

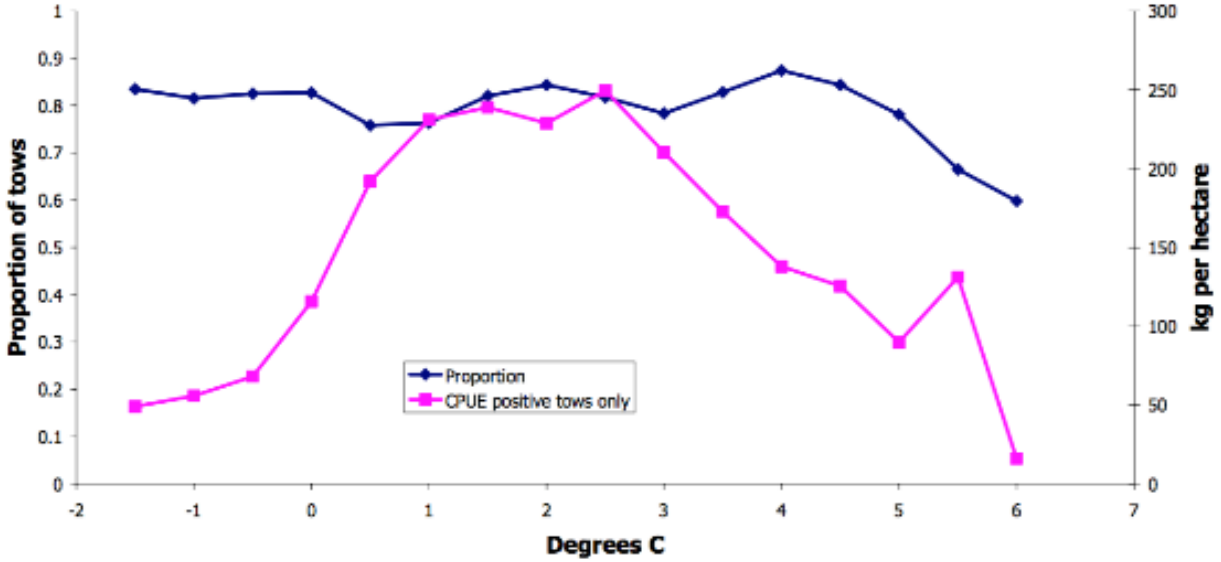


2015 pollock survey—6.4 million t

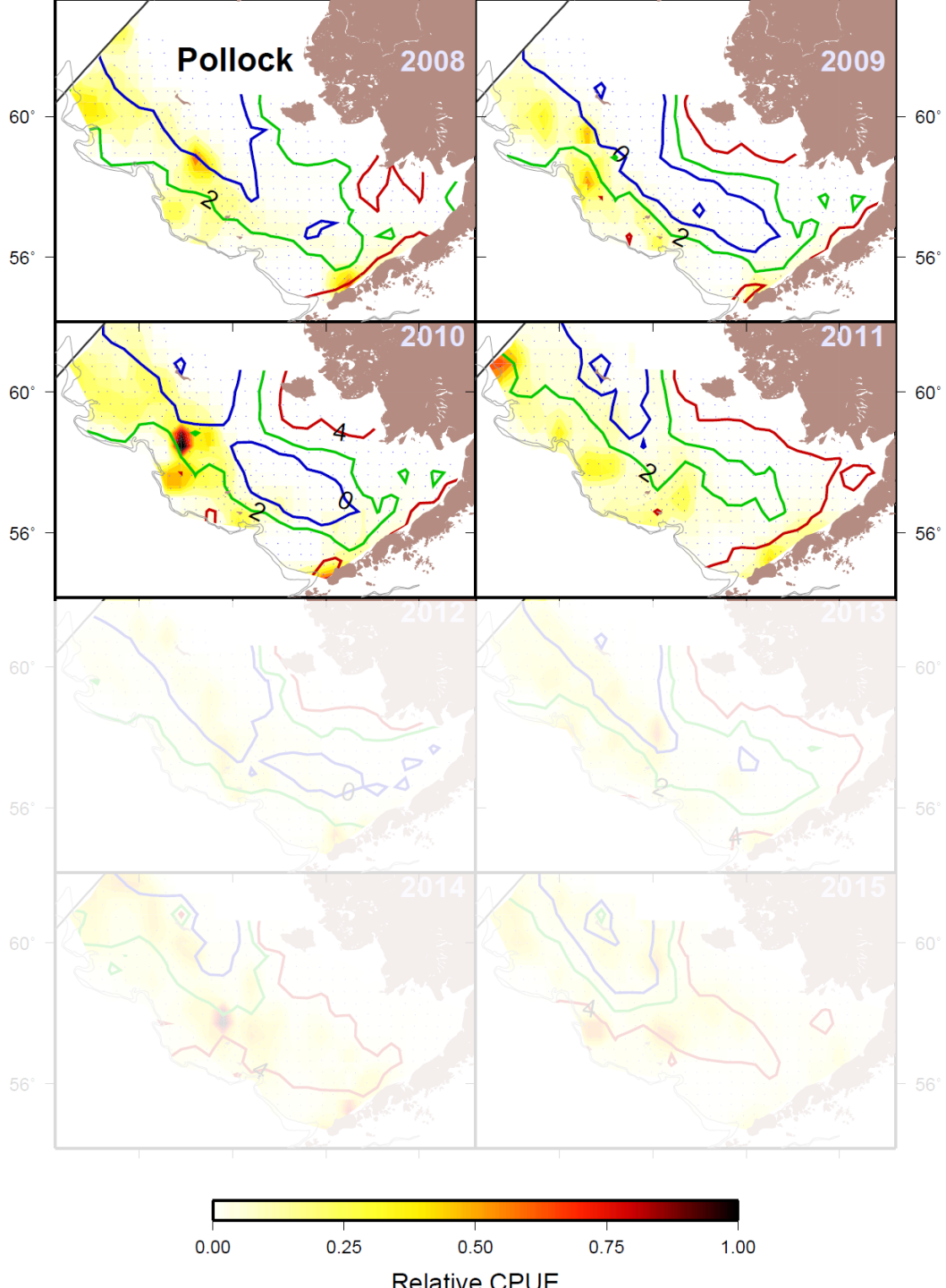


Pollock bottom-trawl survey CPUE and temperature

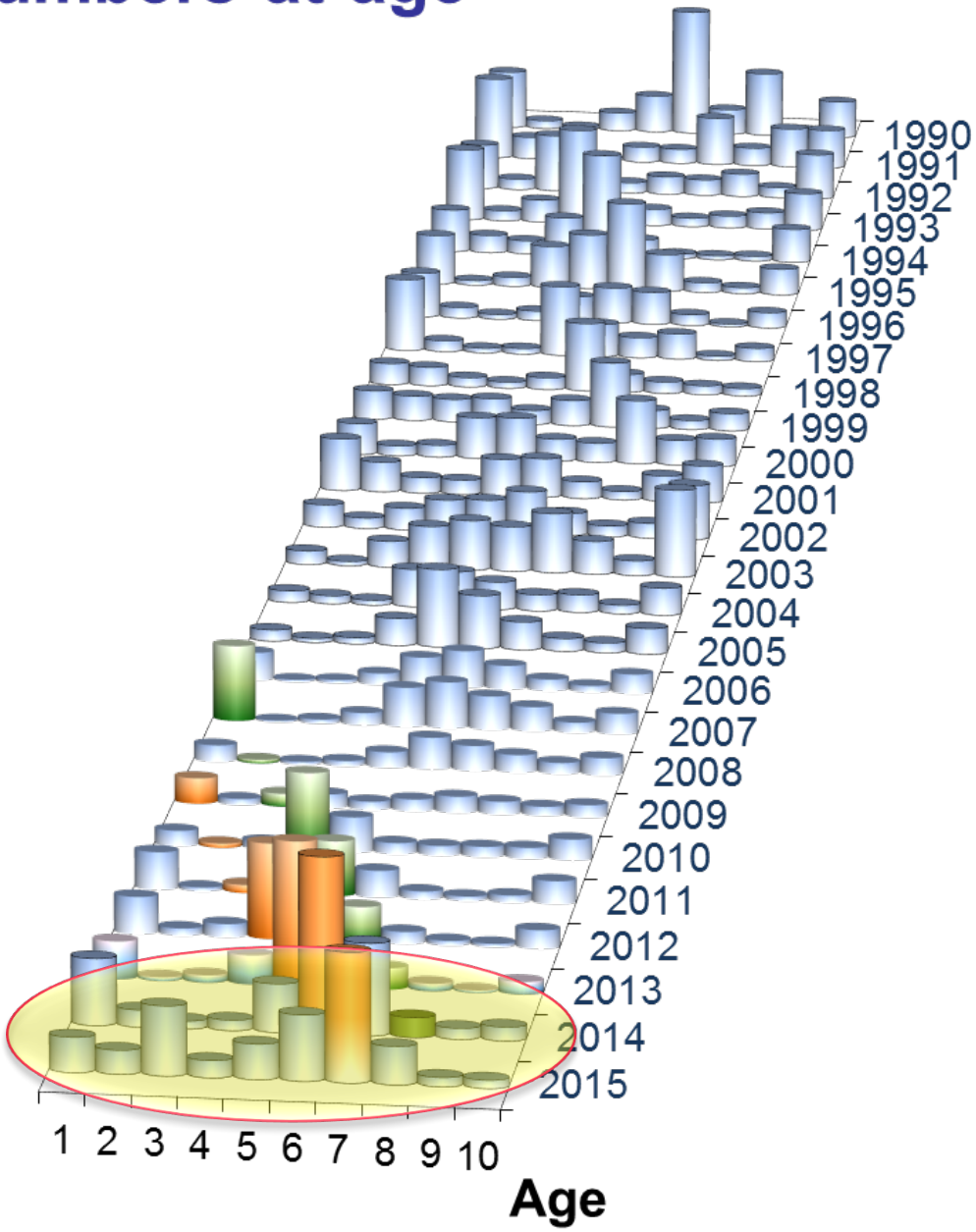




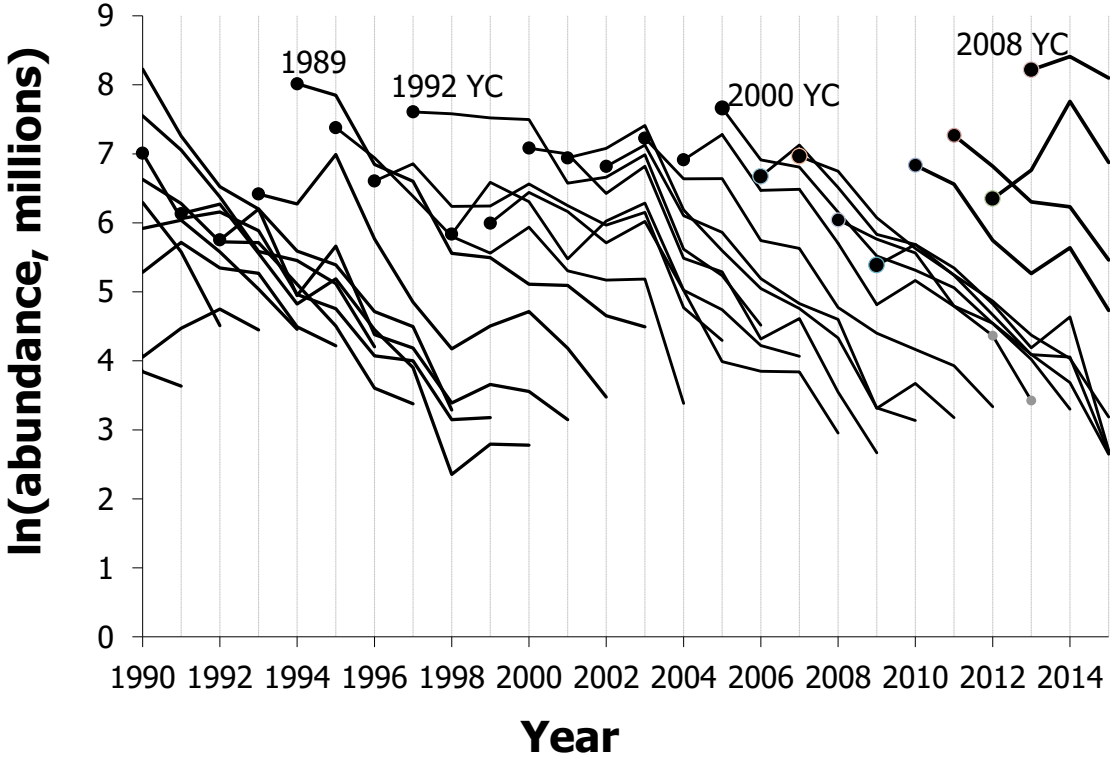
Pollock density and bottom temperatures

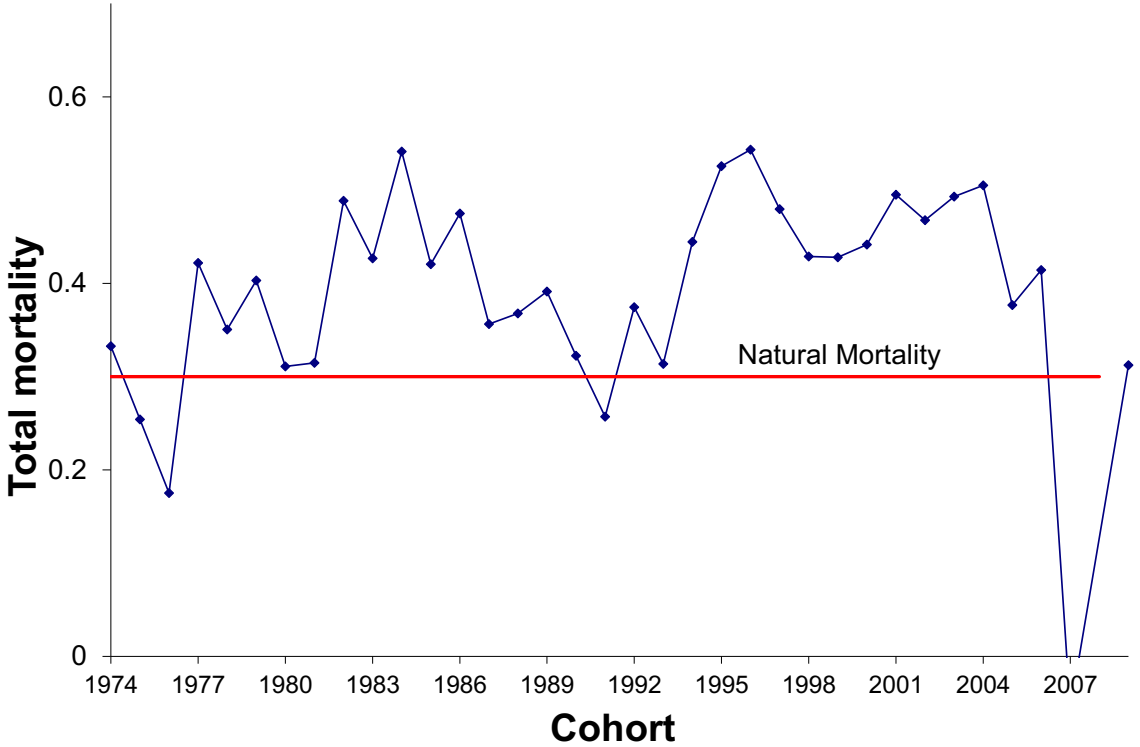


Bottom trawl survey numbers-at-age



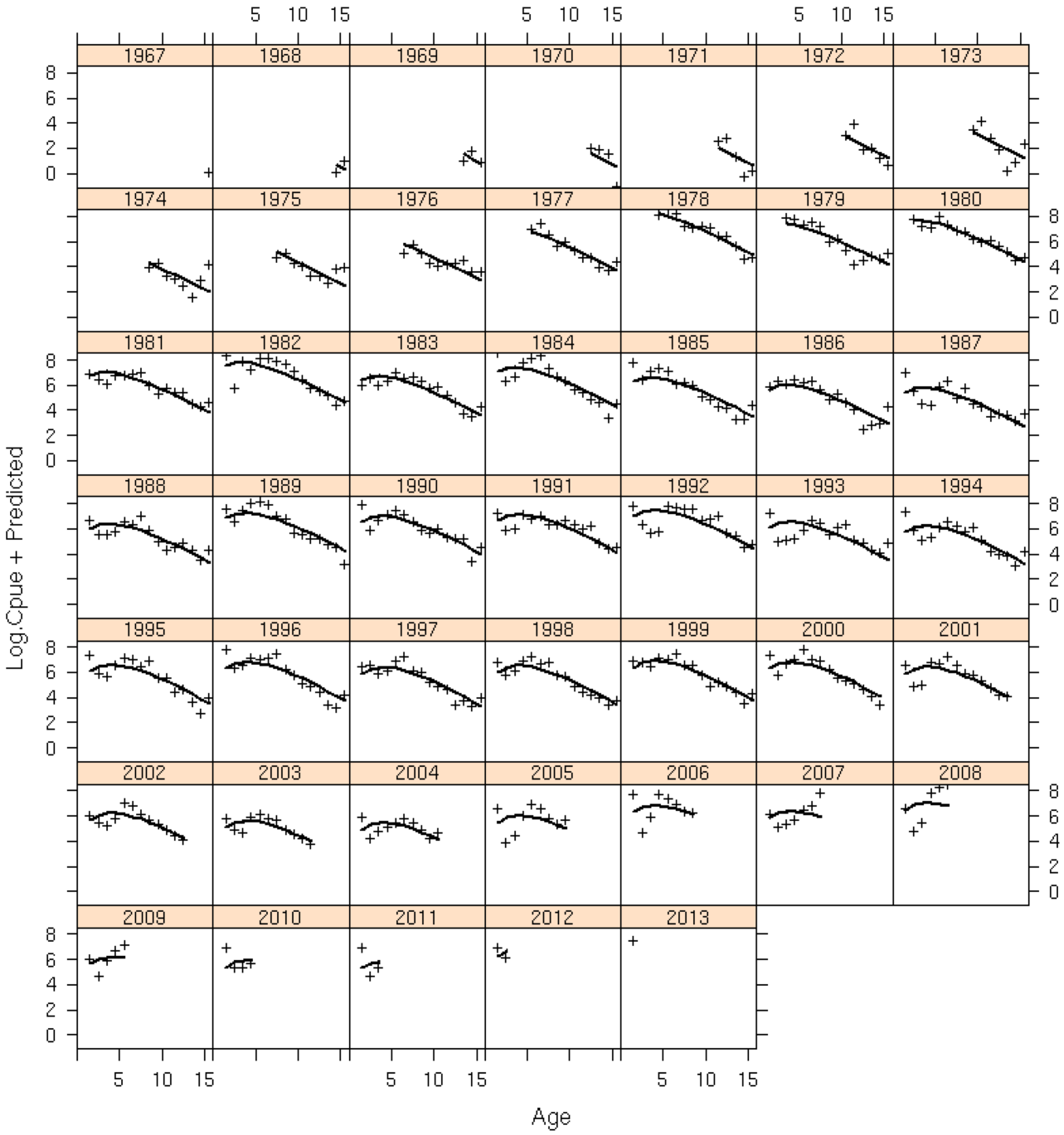
Survey Ln-abundance at age evaluation



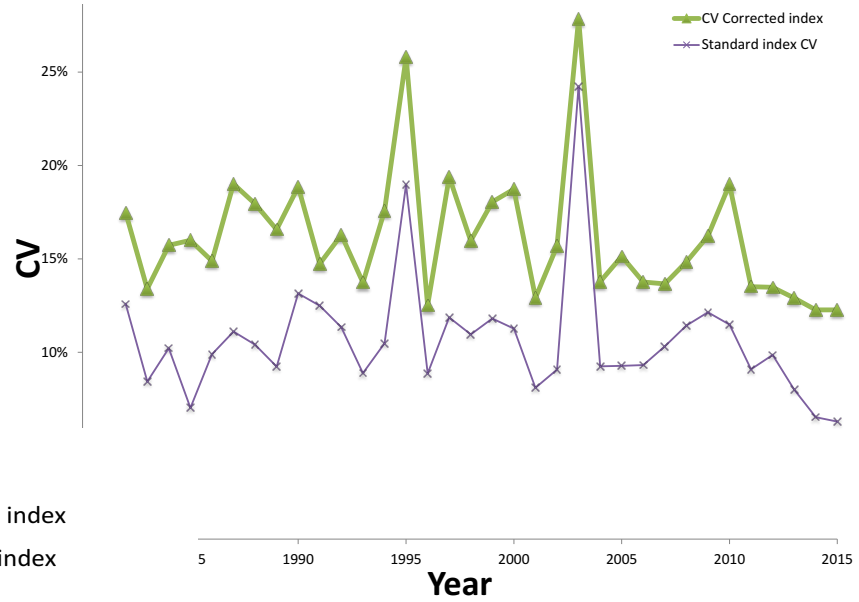


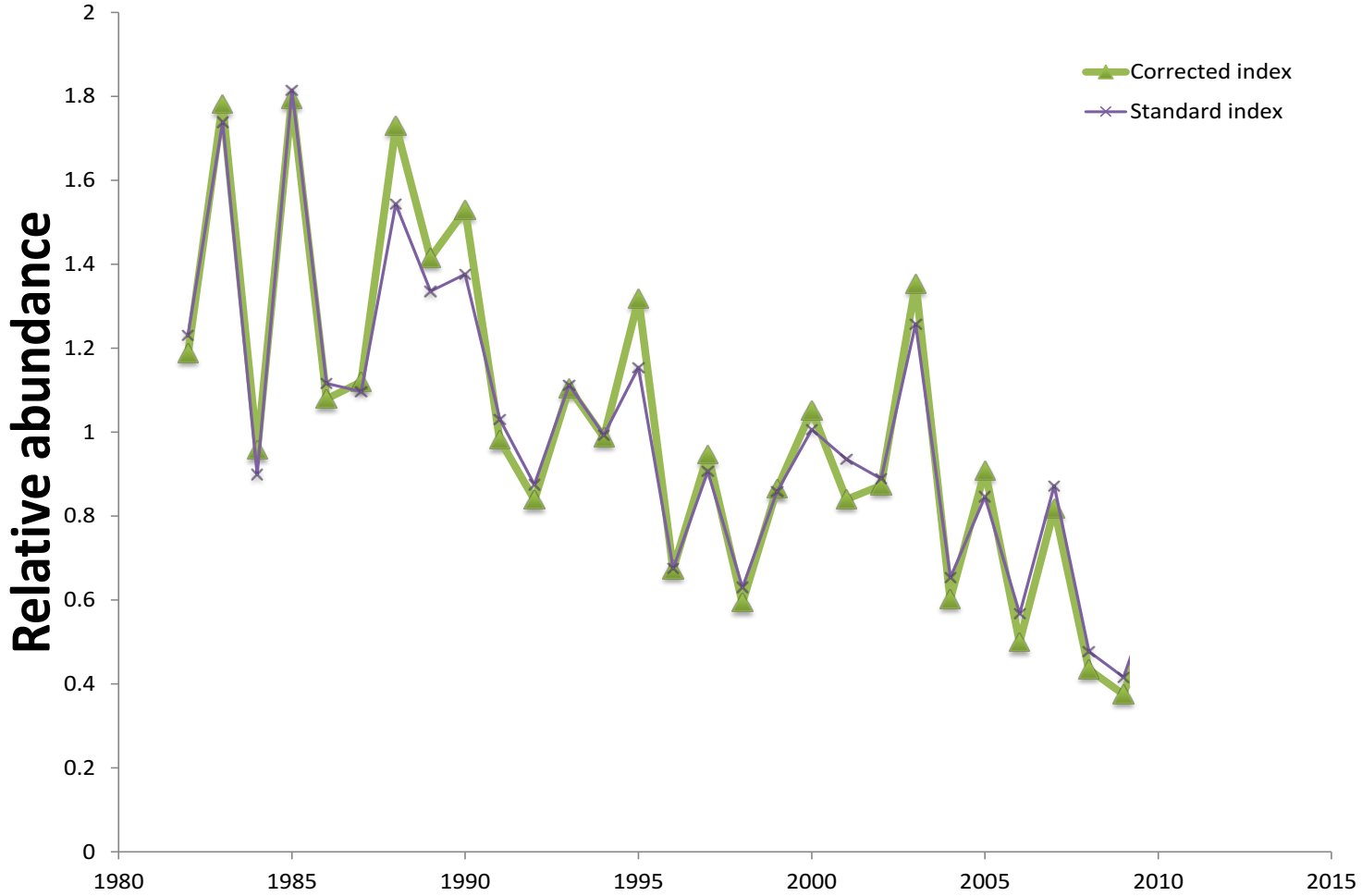
Survey Ln-abundance at age evaluation

- From 2014 assessment

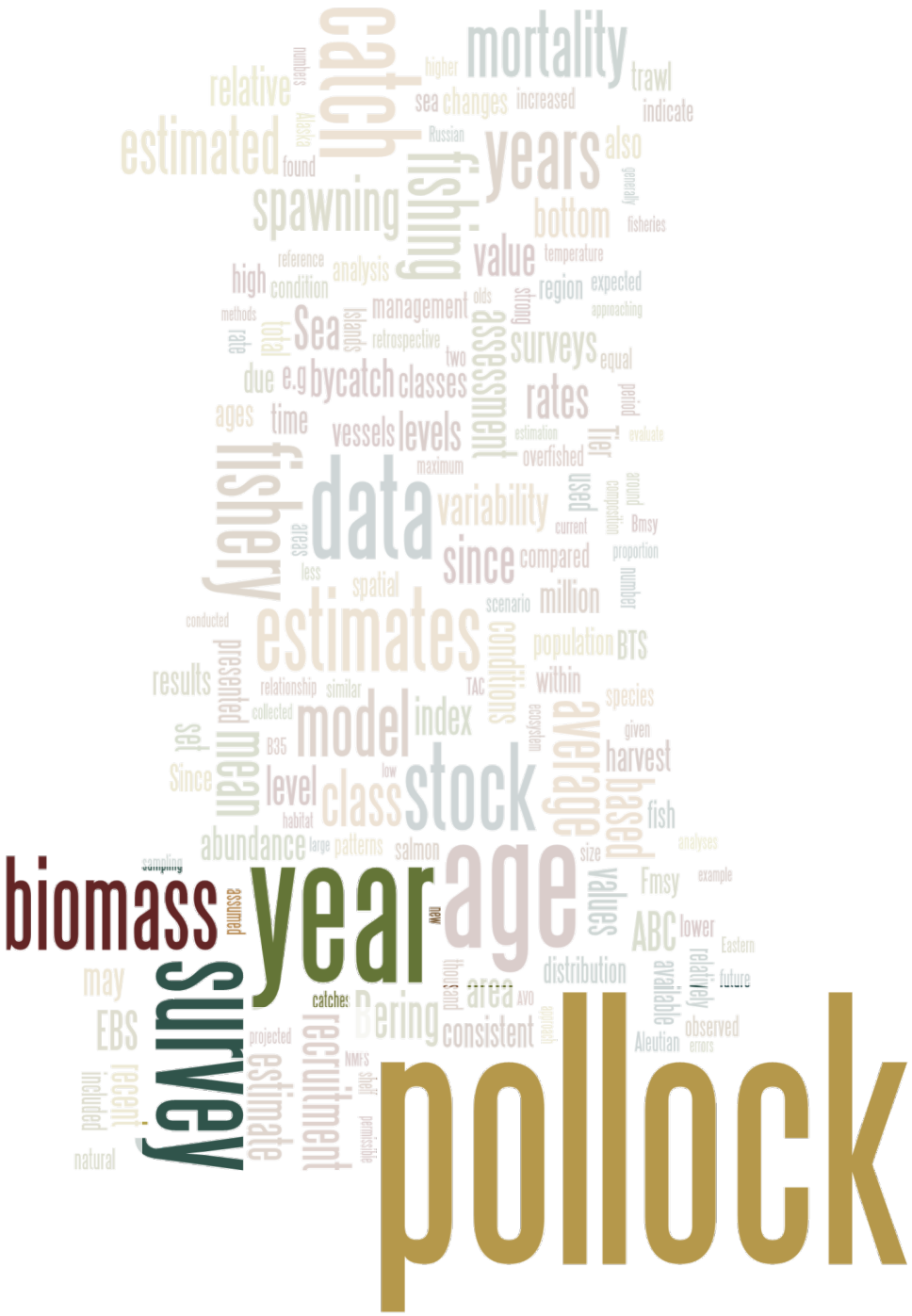


Bottom trawl survey



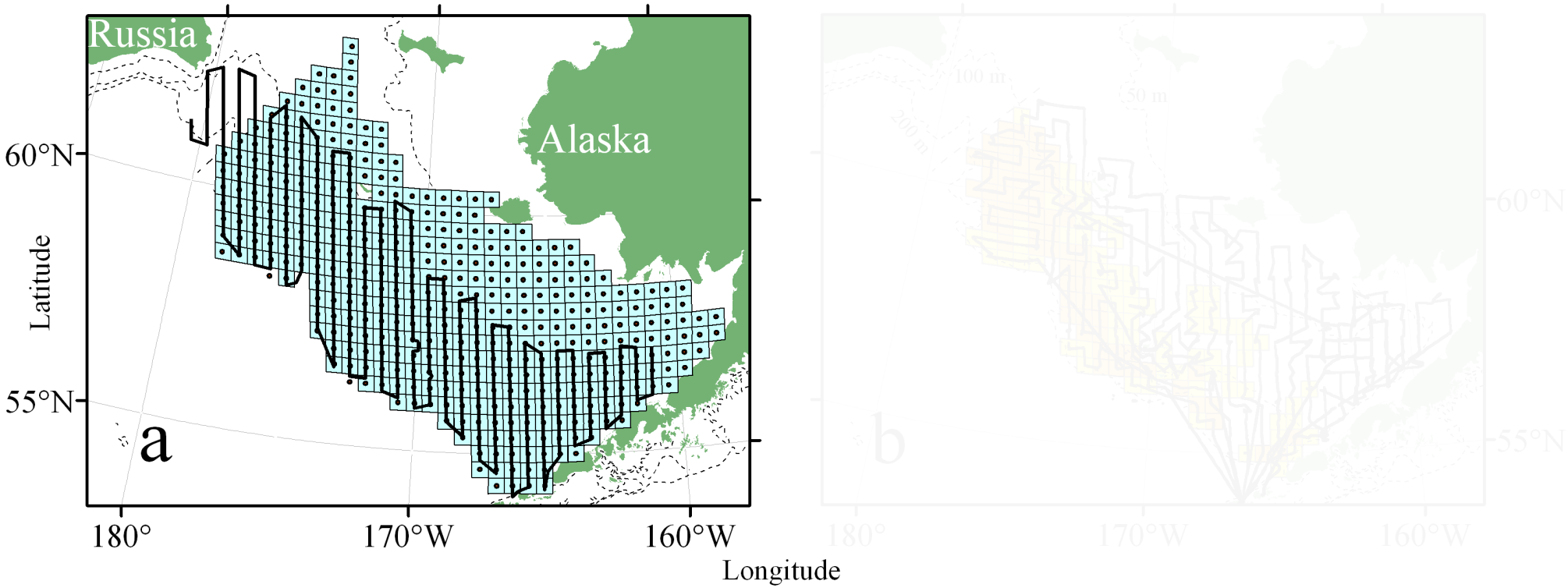


Bottom-trawl survey
+ Acoustic index



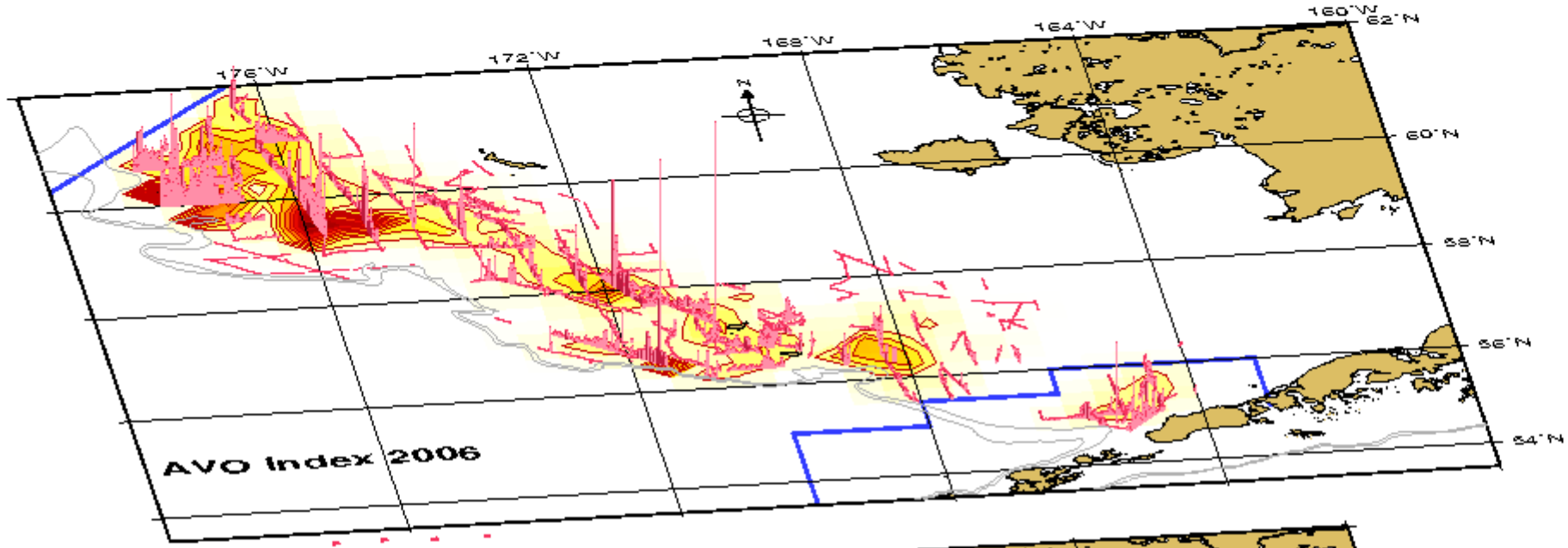
Acoustic Vessels of Oportunity

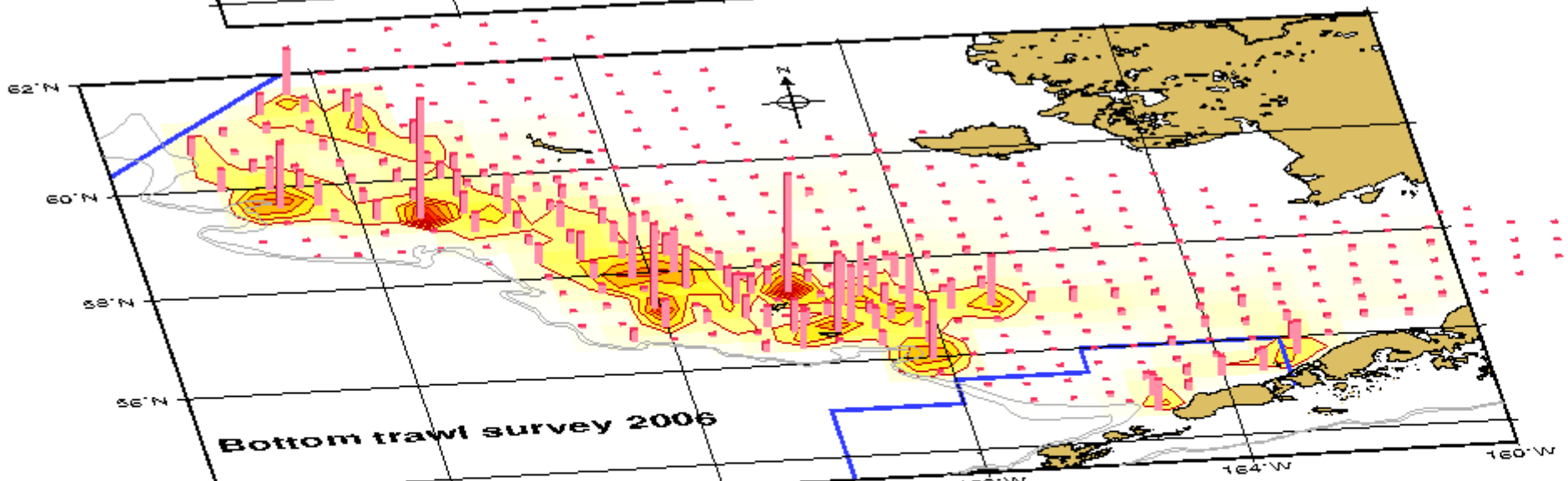
Mid-water acoustic surveys…



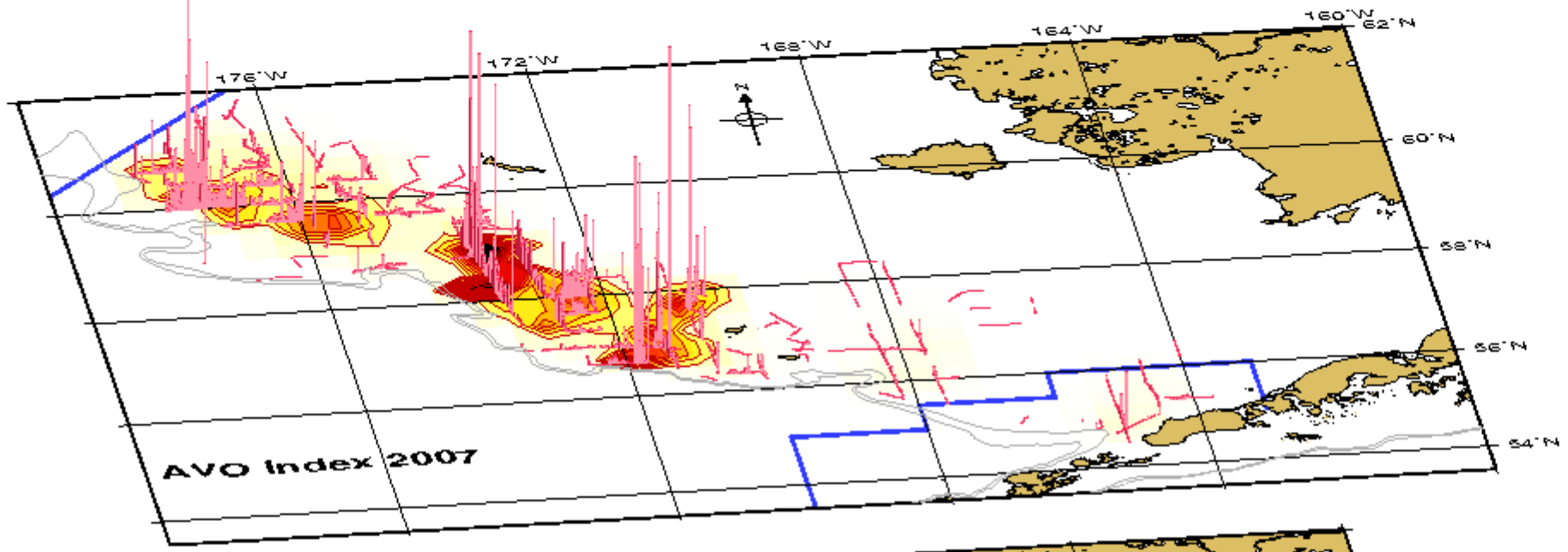
Acoustic
Vessels of
Oportunity

2006


176°W
172°W
168°W
164°W
160°W
62°N
60°N
58°N
56°N
54°N
N
AVO Index 2006


62°N
60°N
58°N
56°N
N
Bottom trawl survey 2006
164°W
160°W

2007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164°W
160°W
62°N
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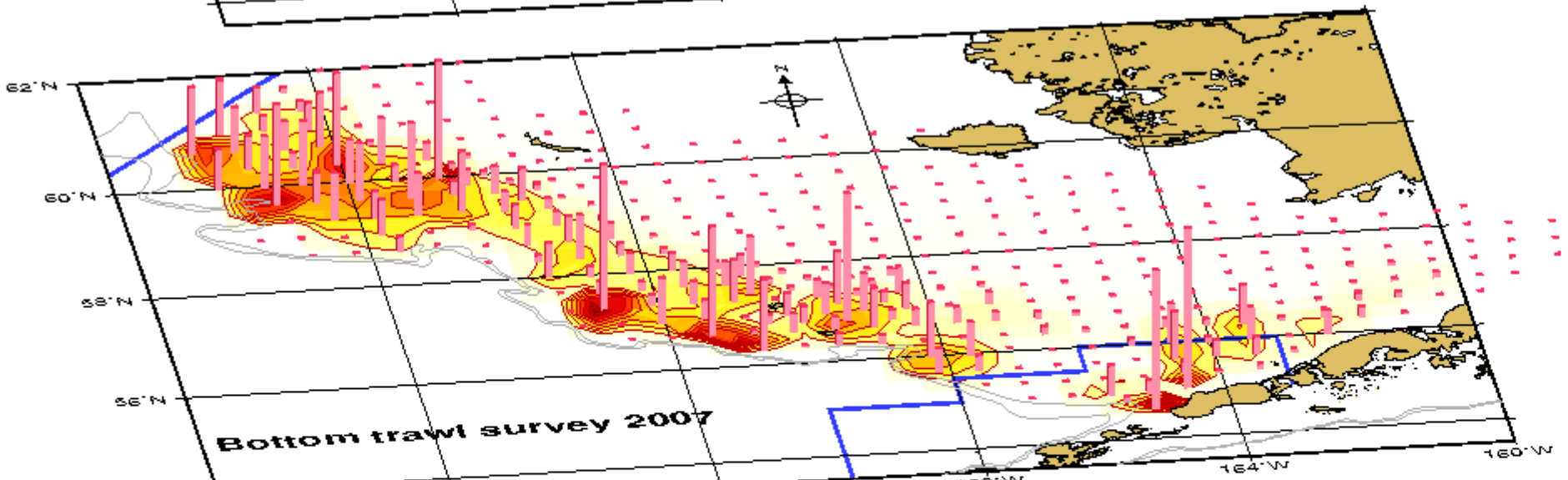
58°N
56°N
54°N
N
AVO Index 2007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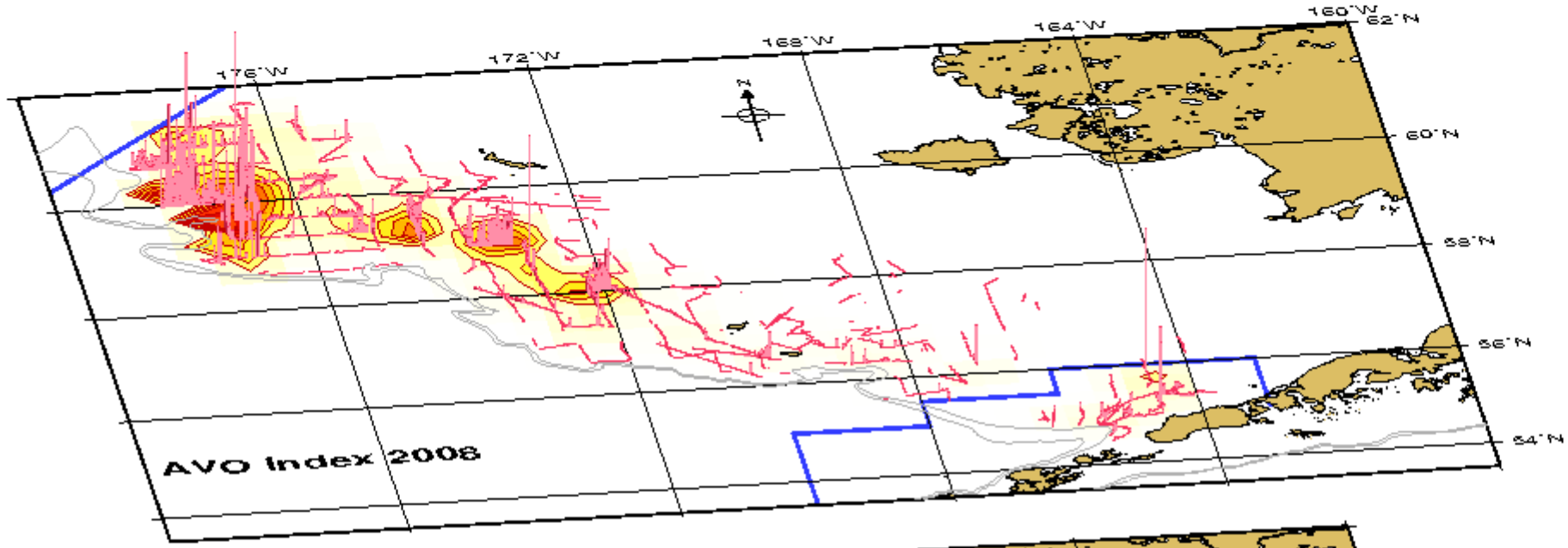
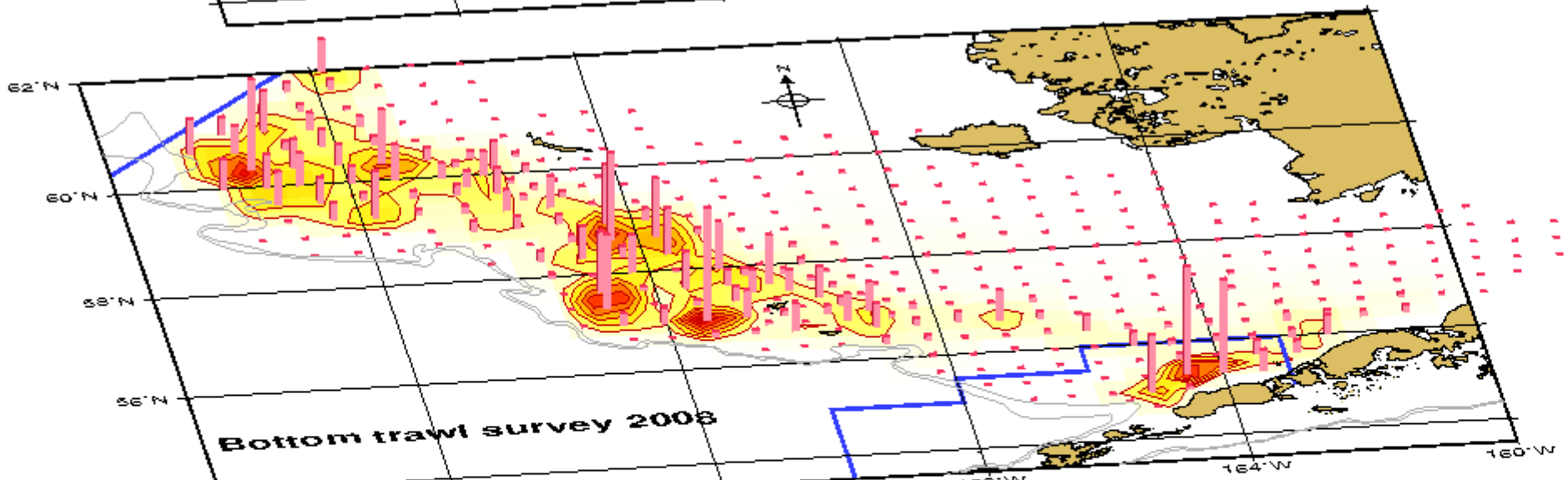
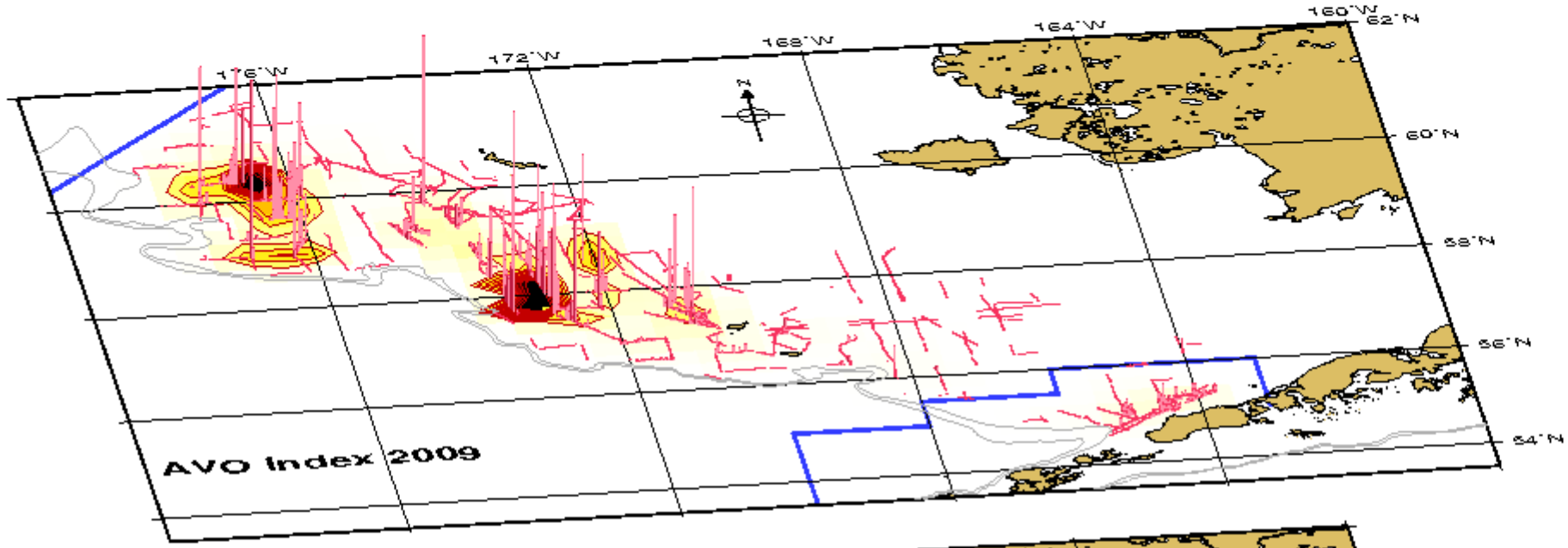
60°N
58°N
56°N
N
Bottom trawl survey 2007
164°W
160°W

2008


176°W
172°W
168°W
164°W
160°W
62°N
60°N
58°N
56°N
54°N
N
AVO Index 2008


62°N
60°N
58°N
56°N
N
Bottom trawl survey 2008
164°W
160°W

2009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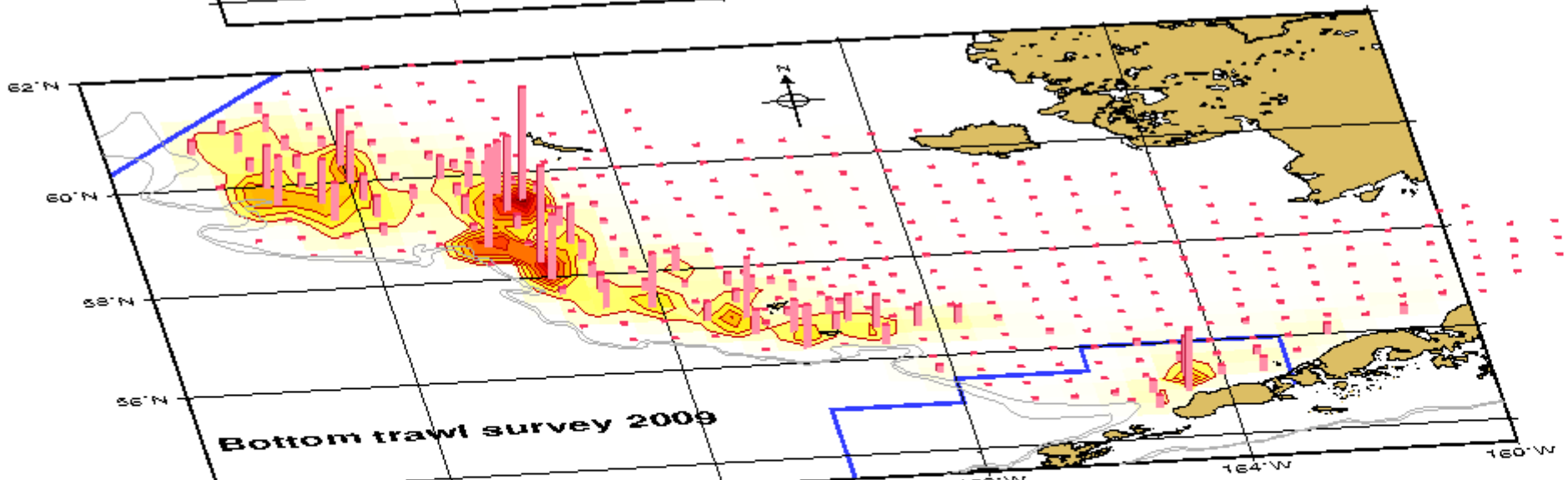
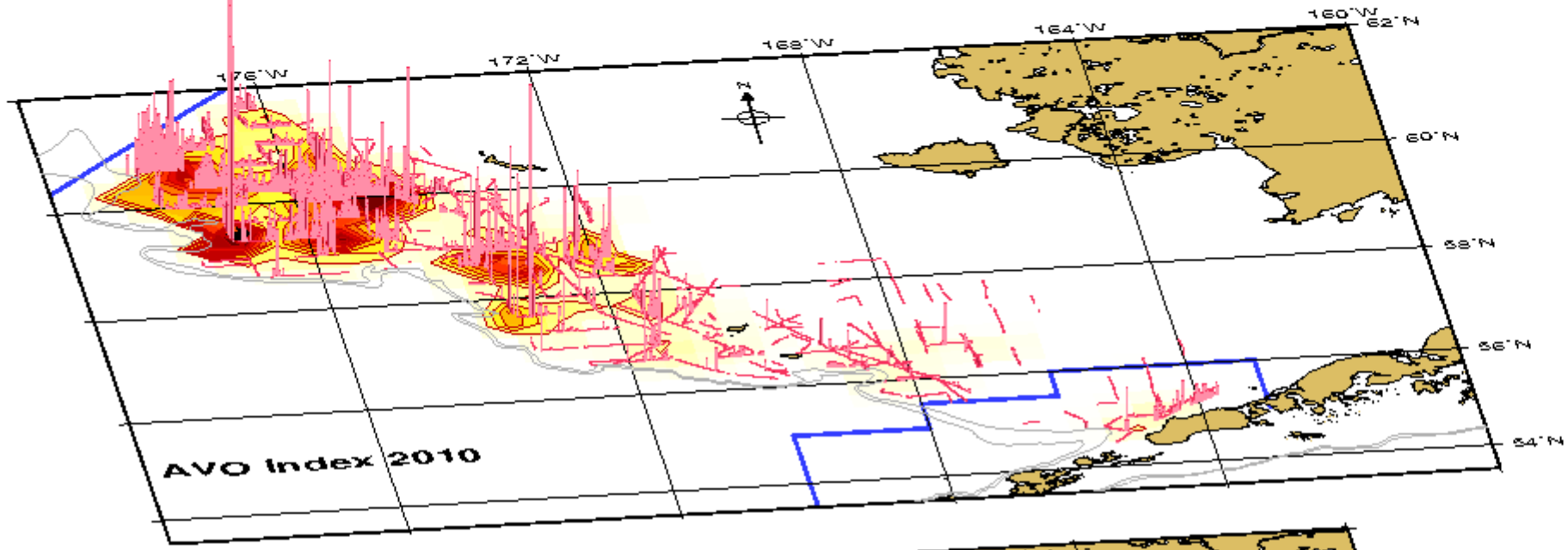
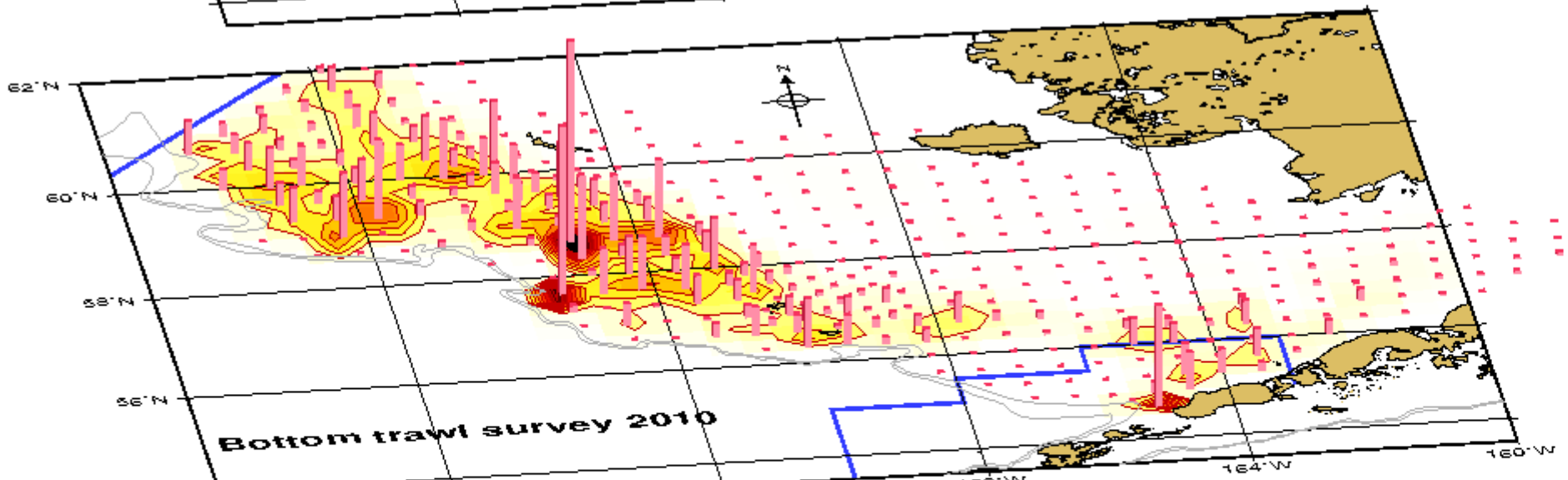
172°W
168°W
164°W
160°W
62°N
60°N
58°N
56°N
54°N
N
AVO Index 2009


62°N
60°N
58°N
56°N
N
Bottom trawl survey 2009
164°W
160°W

2010


176°W
172°W
168°W
164°W
160°W
62°N
60°N
58°N
56°N
54°N
N
AVO Index 2010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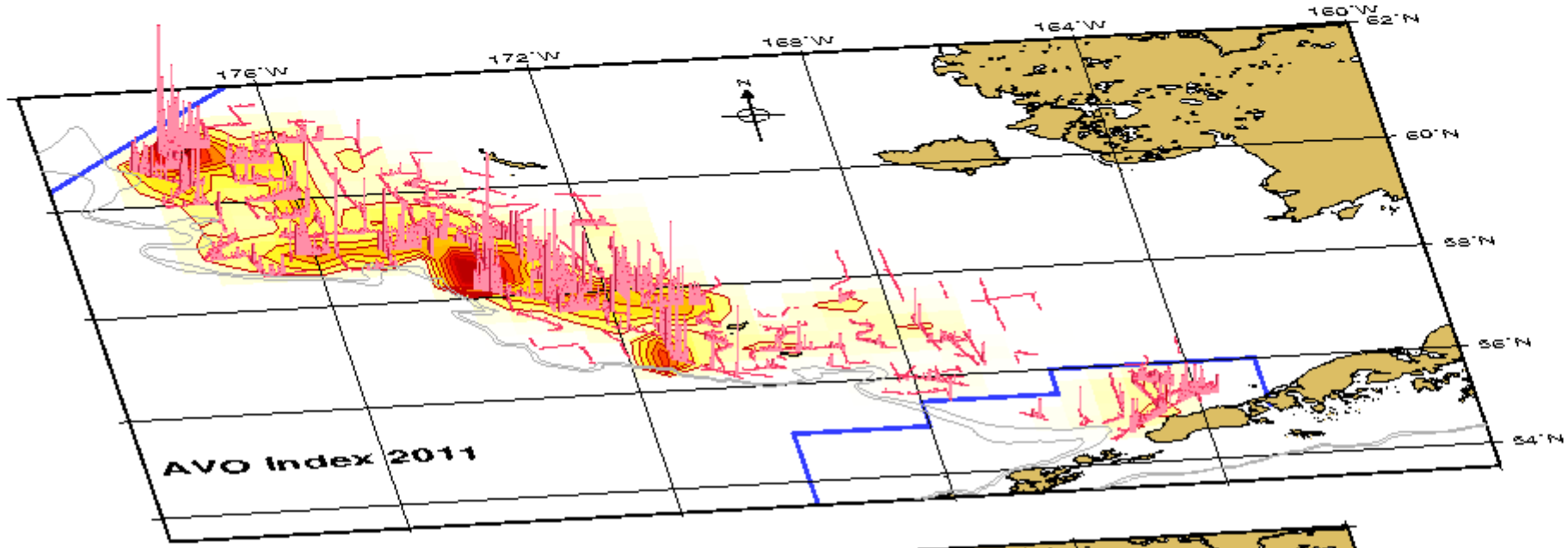
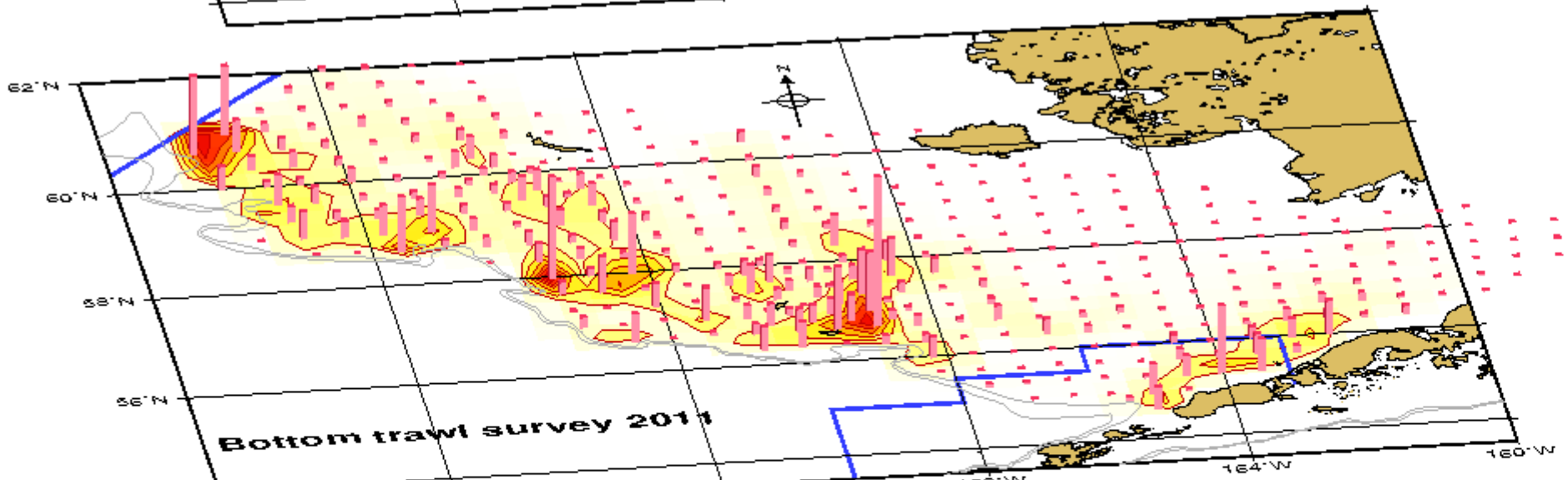
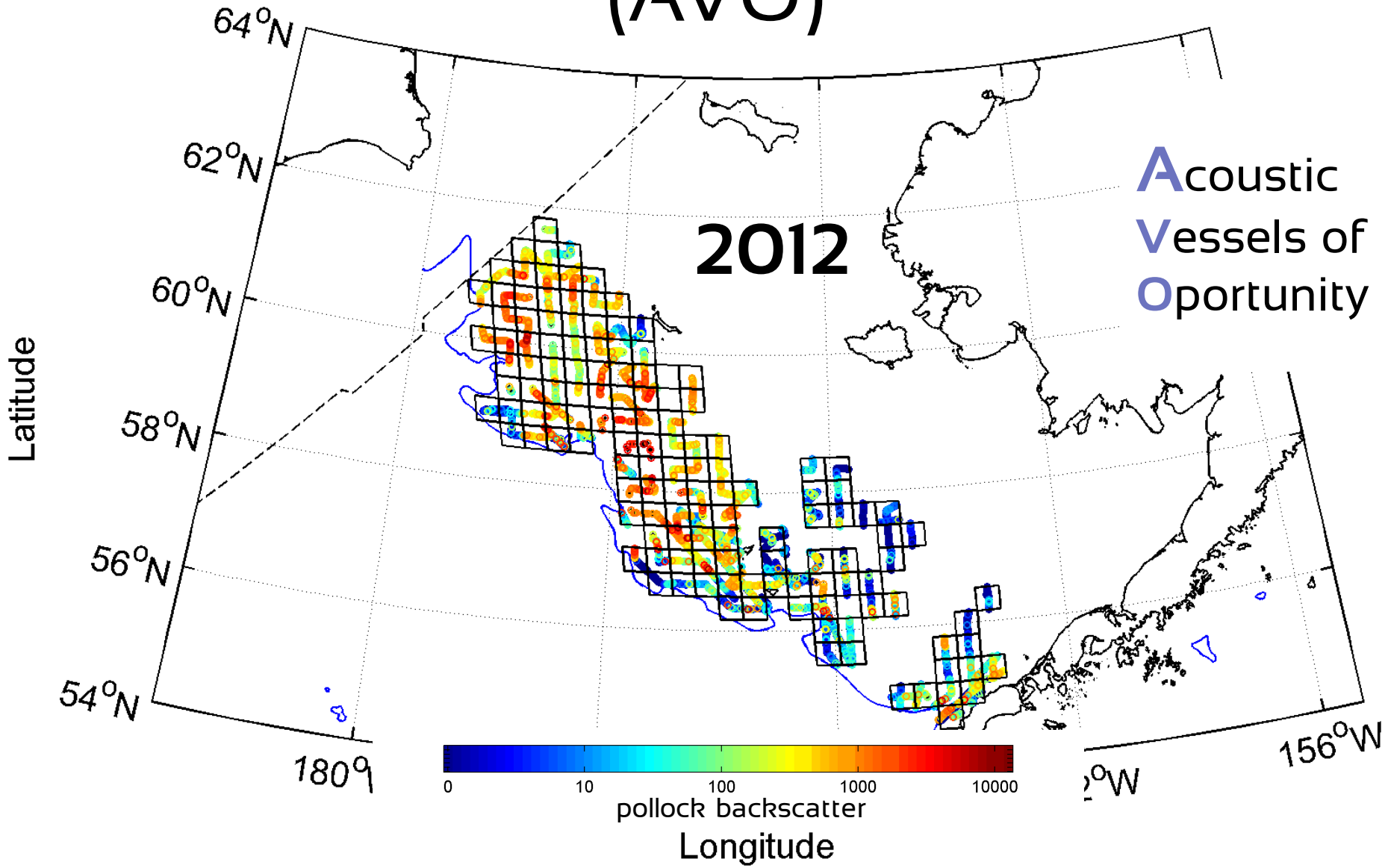
60°N
58°N
56°N
N
Bottom trawl survey 2010
164°W
160°W

2011

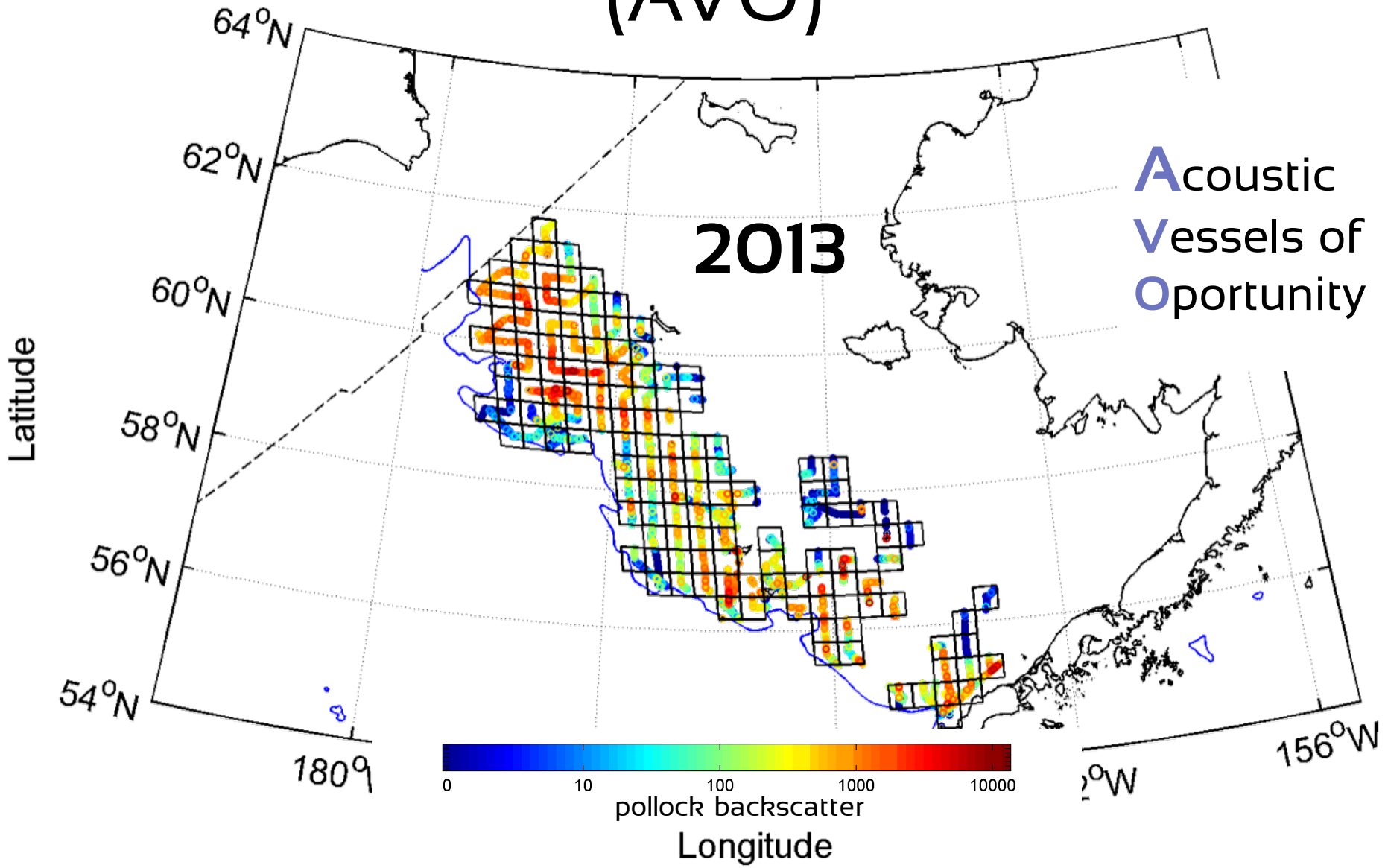

176°W
172°W
168°W
164°W
160°W
62°N
60°N
58°N
56°N
54°N
N
AVO Index 2011


62°N
60°N
58°N
56°N
N
Bottom trawl survey 2011
164°W
160°W

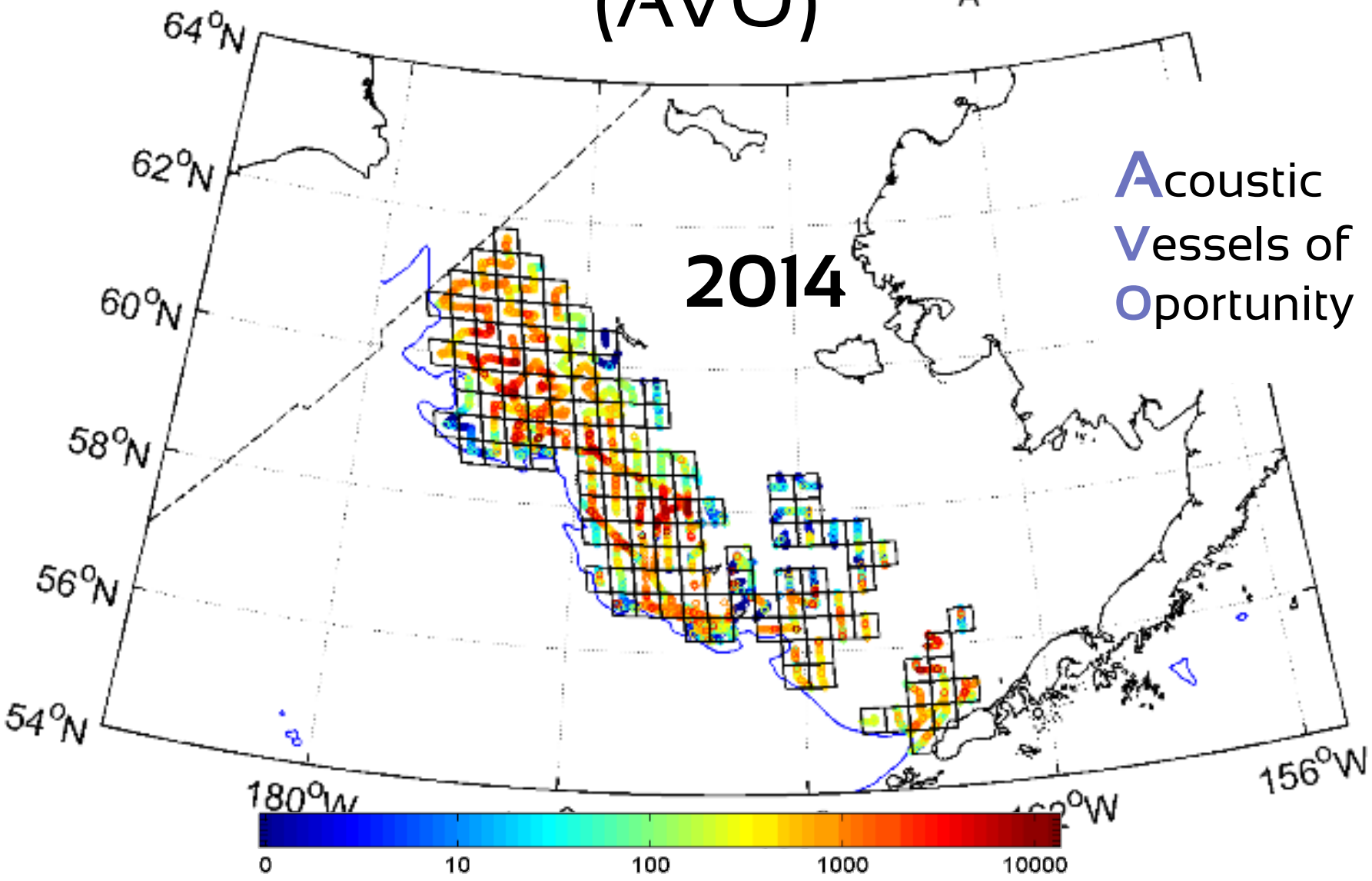
Acoustic vessels of opportunity (AVO)



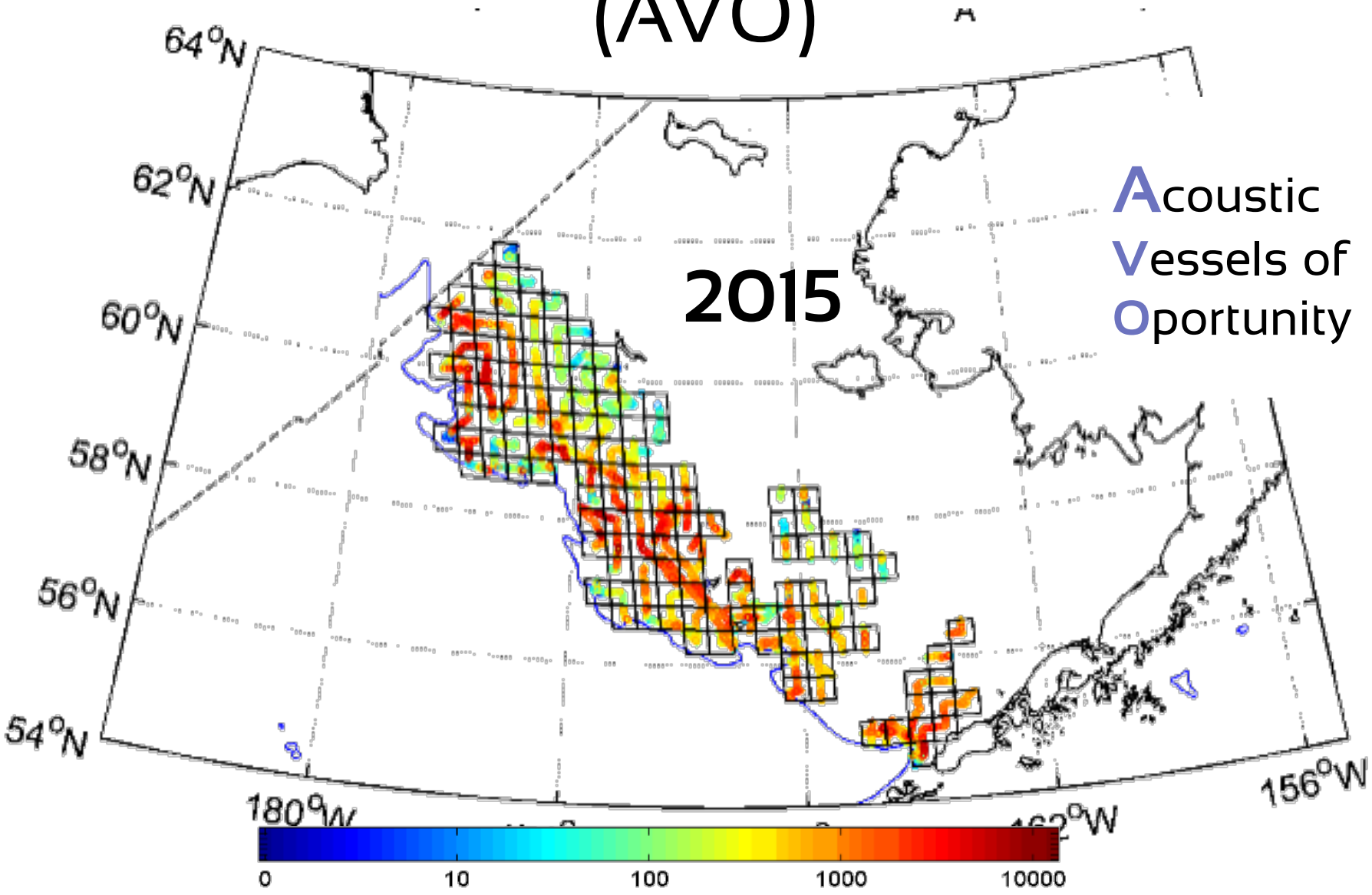
Acoustic vessels of opportunity (AVO)



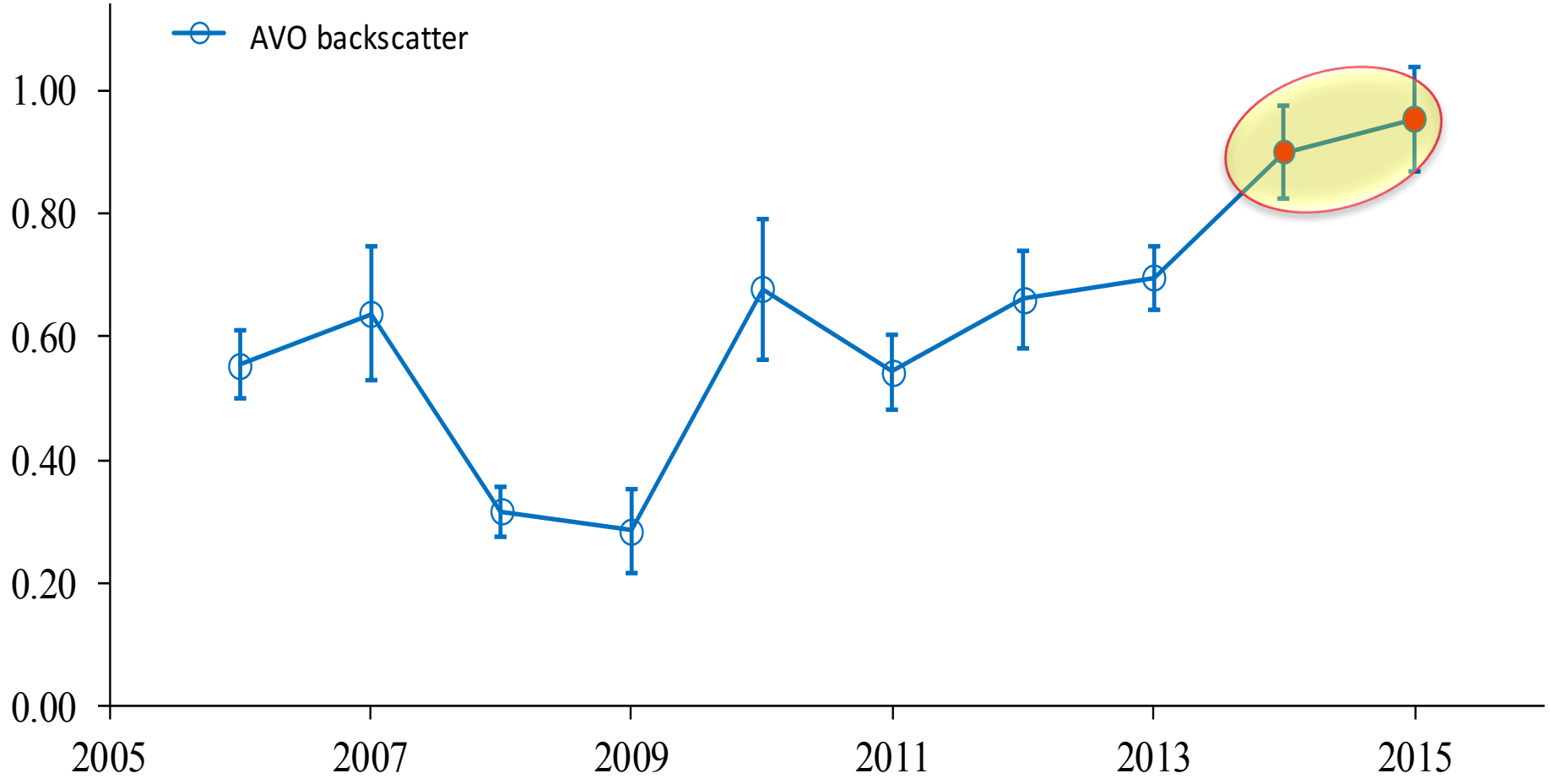
Acoustic vessels of opportunity (AVO)



Acoustic vessels of opportunity (AVO)

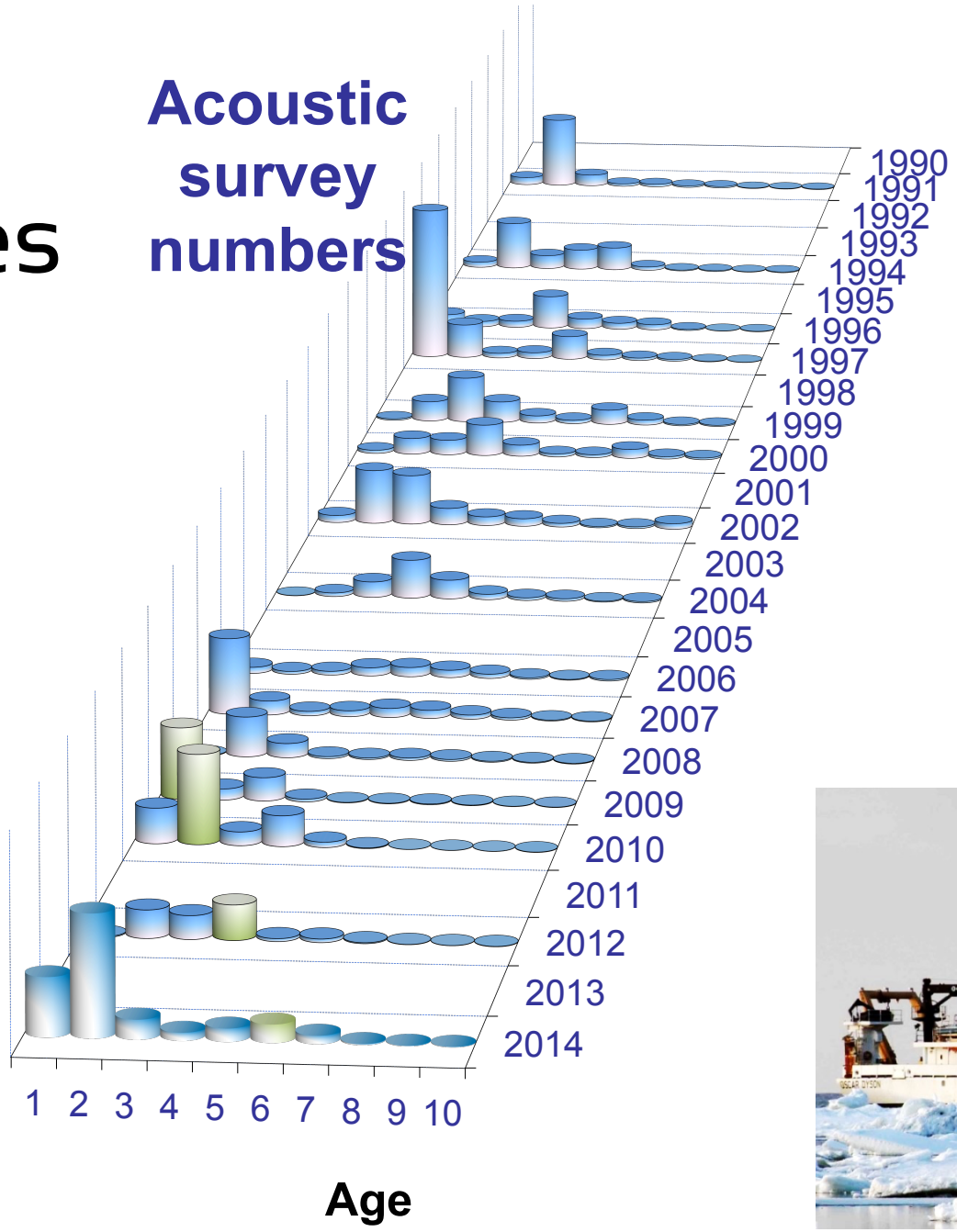


Opportunistic Acoustic survey index

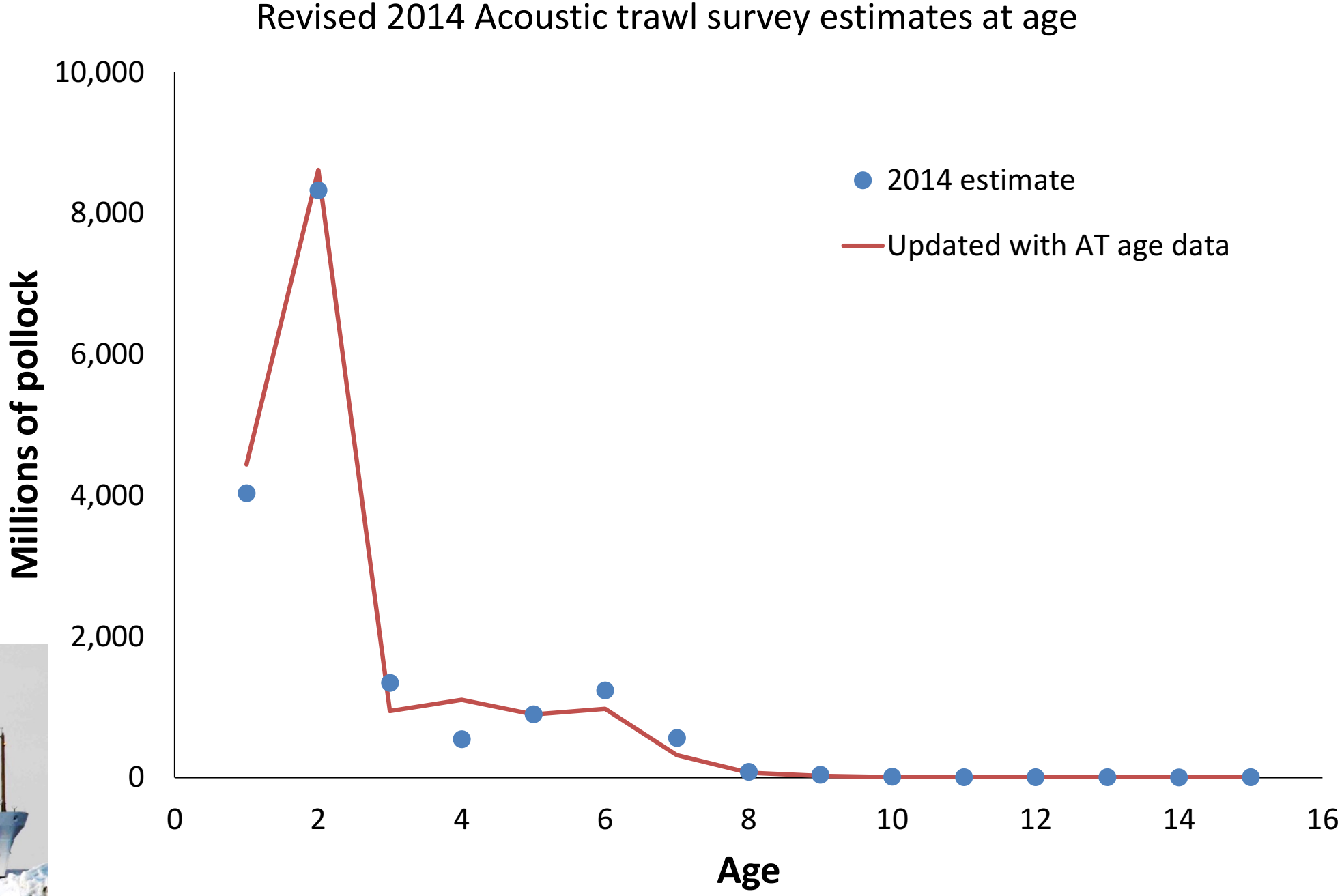


Acoustic trawl survey age estimates

From 2014 assessment



2015 Updating Acoustic age compositions

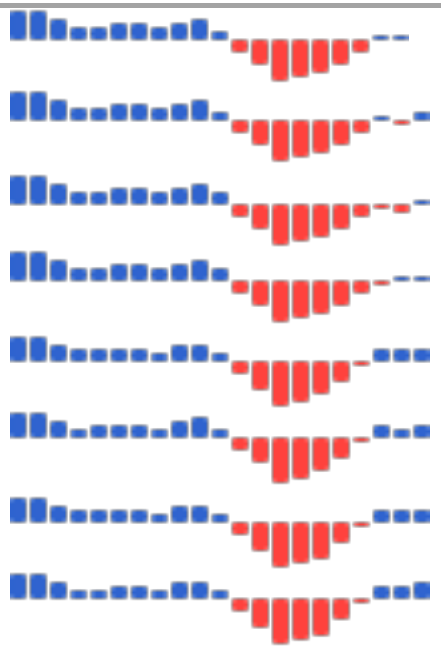


Model results

Sequential add of new data

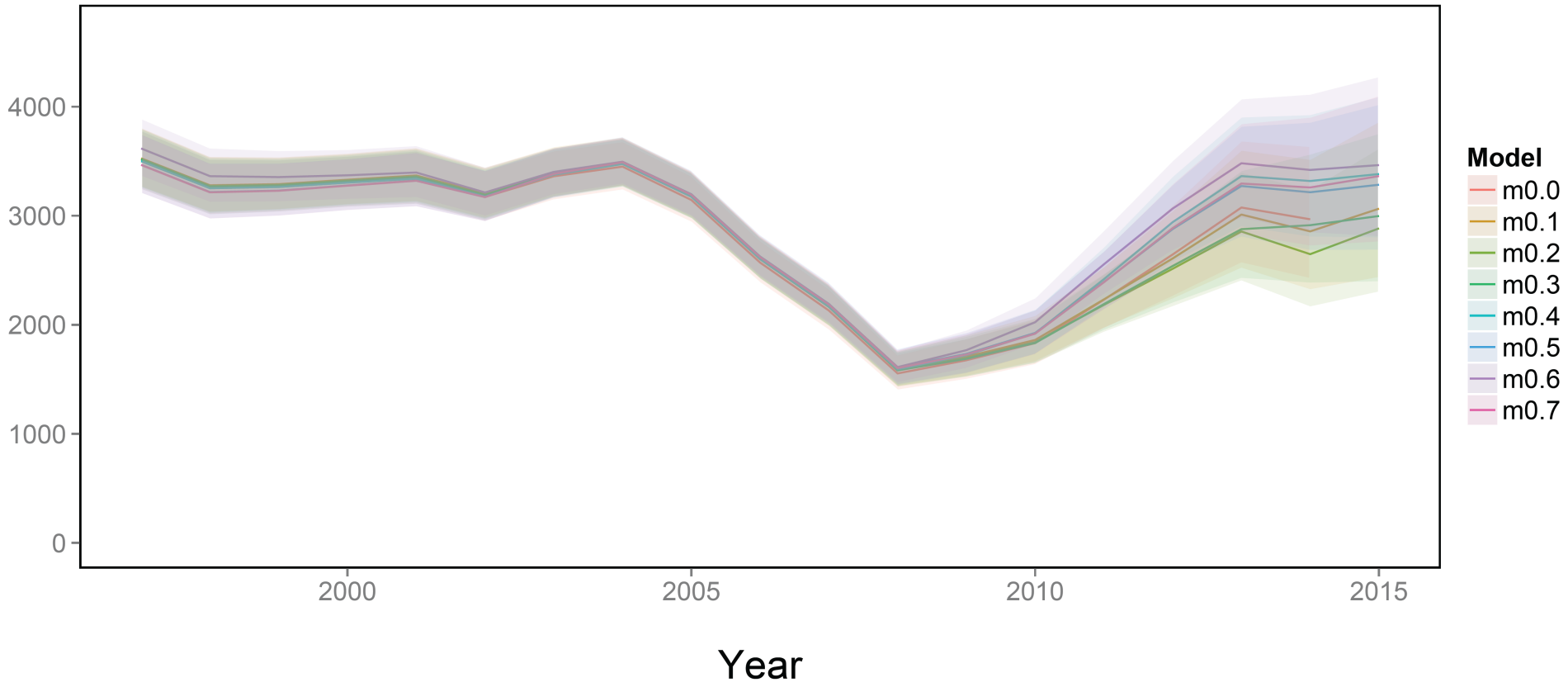
Model evaluation

A sequence of models were developed that evaluated sensitivities to new data which included updating the catch biomass for 2014 and estimated levels for 2015 along with the 2014 fishery mean weights-at-age. As in past years, a set of models showing the impact of new data was constructed, this year with a summary of the impact of these changes on the relative spawning biomass (last column):

Model		2015 catch	AT Age revised	2014 Fish Ages	BTS Std Index	BTS Alt Index	AVO Update	Spawning biomass relative to the average from 1995-2015
0.0	2014 assessment							
0.1	With updated catch and extended to 2015	X						
0.2	As 0.1 but with updated AT Age data	X	X					
0.3	As 0.2 but with 2014 fishery age	X	X	X				
0.4	As 0.3 but with standard BTS data added	X	X	X	X			
0.5	As 0.3 but with corrected BTS index data added	X	X	X		X		
0.6	As 0.4 but with AVO data added	X	X	X	X		X	
0.7	As 0.5 but with AVO data added	X	X	X		X	X	

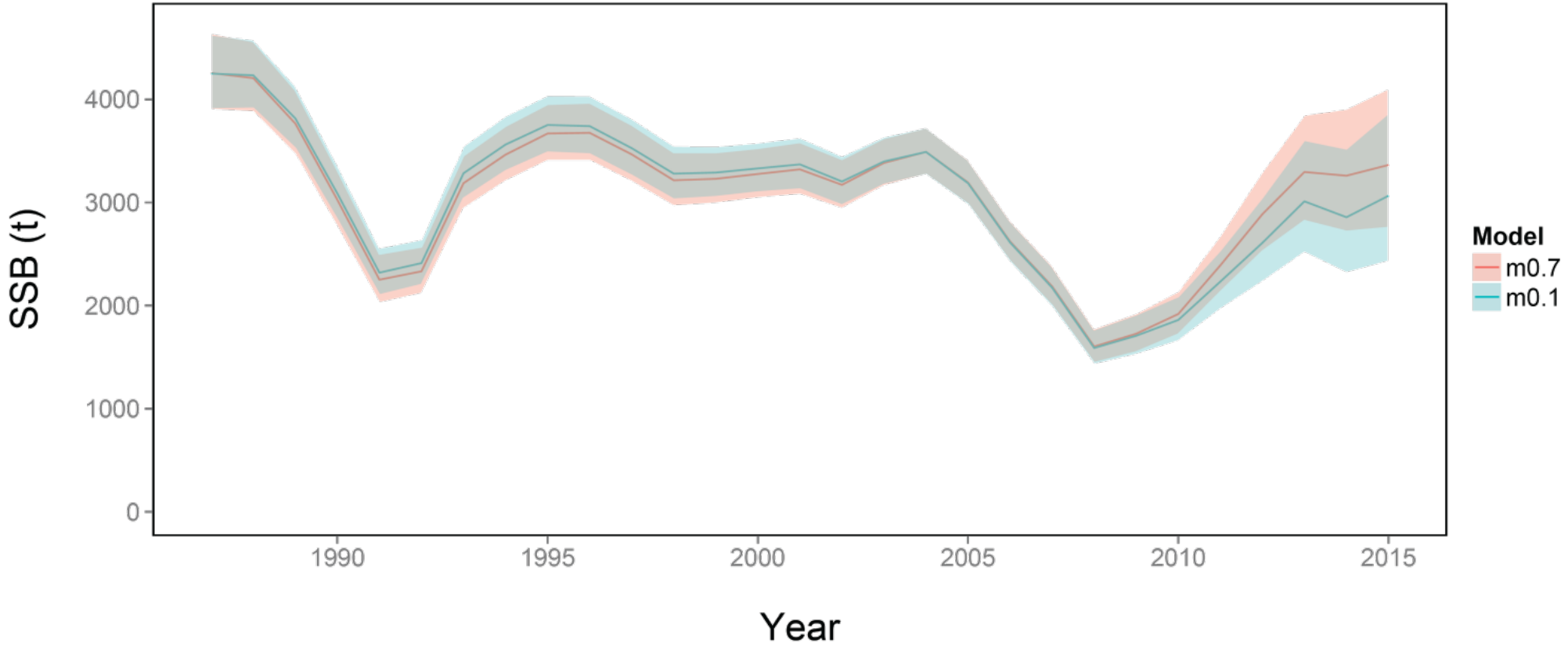
Spawning biomass in thousands of tons

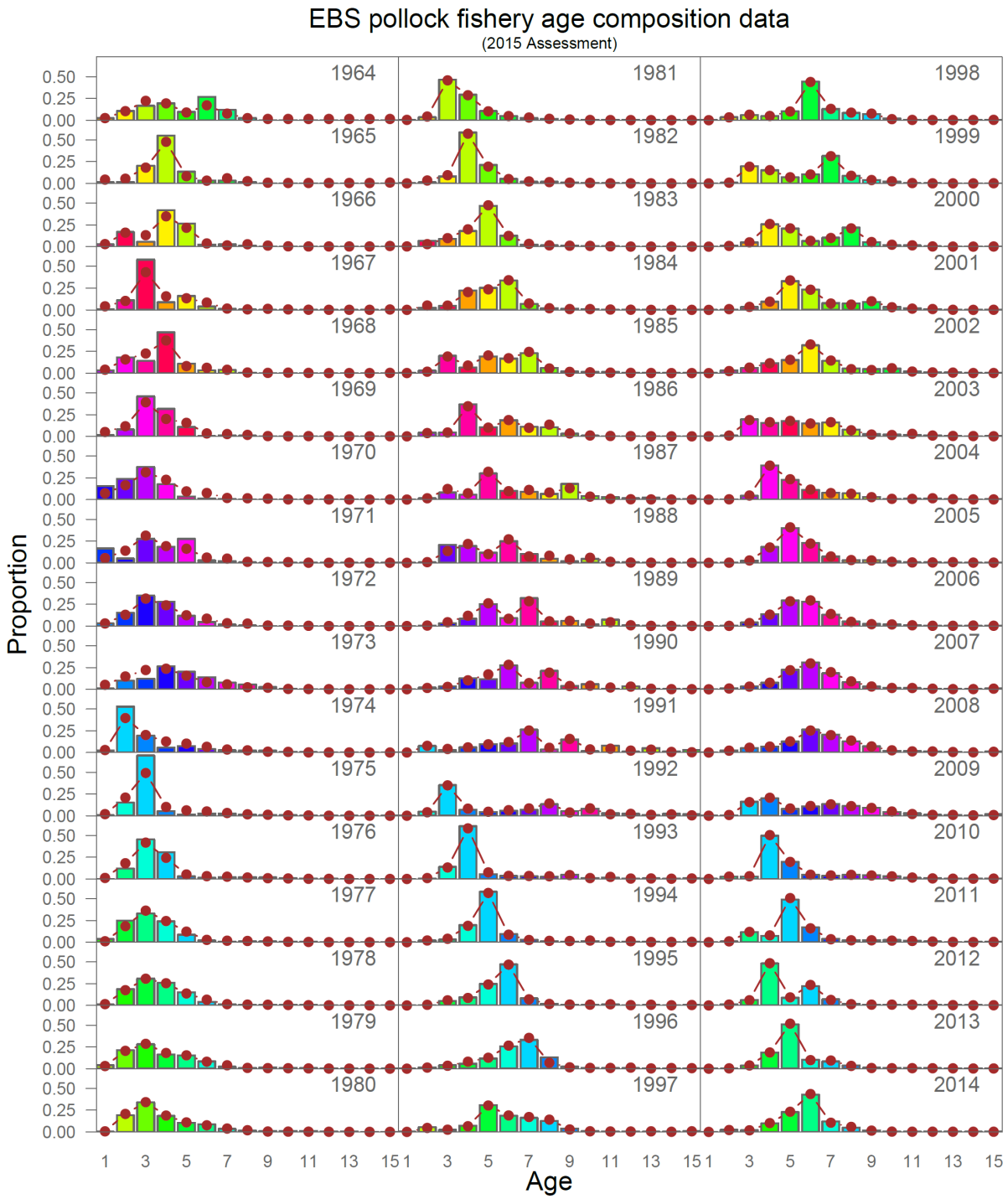
Effect of new data for 2015



Spawning biomass in thousands of tons

Effect of new data for 2015




EBS pollock fishery age composition data
(2015 Assessment)
Proportion
Age
0.50
0.25
0.00
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
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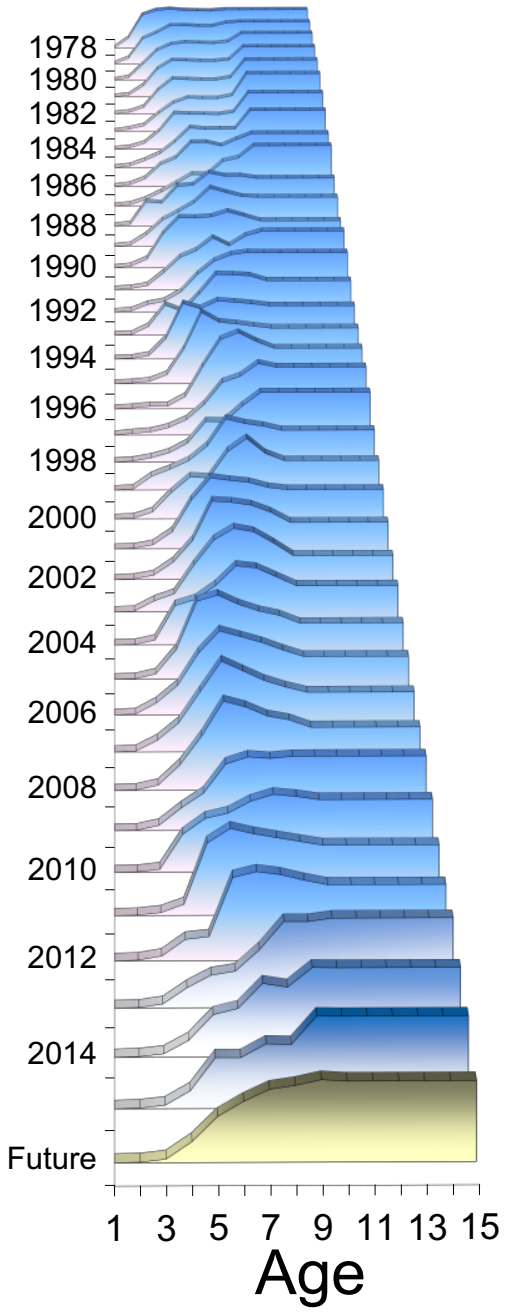
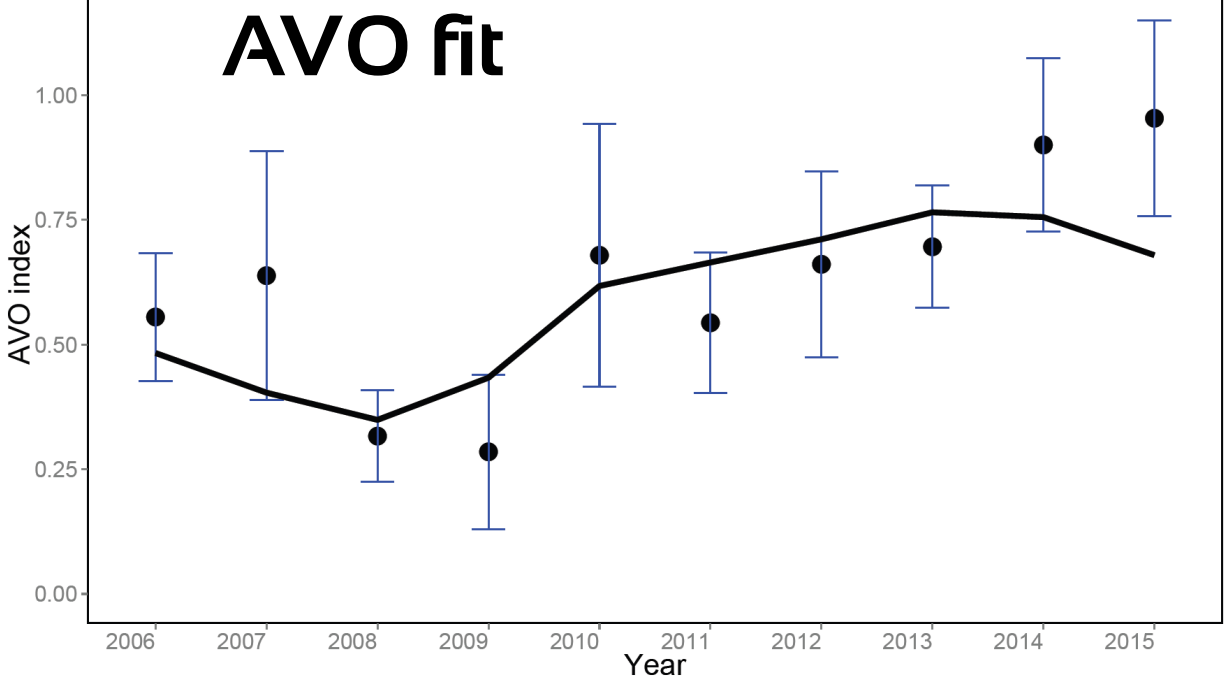
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
1 3 5 7 9 11 13 15

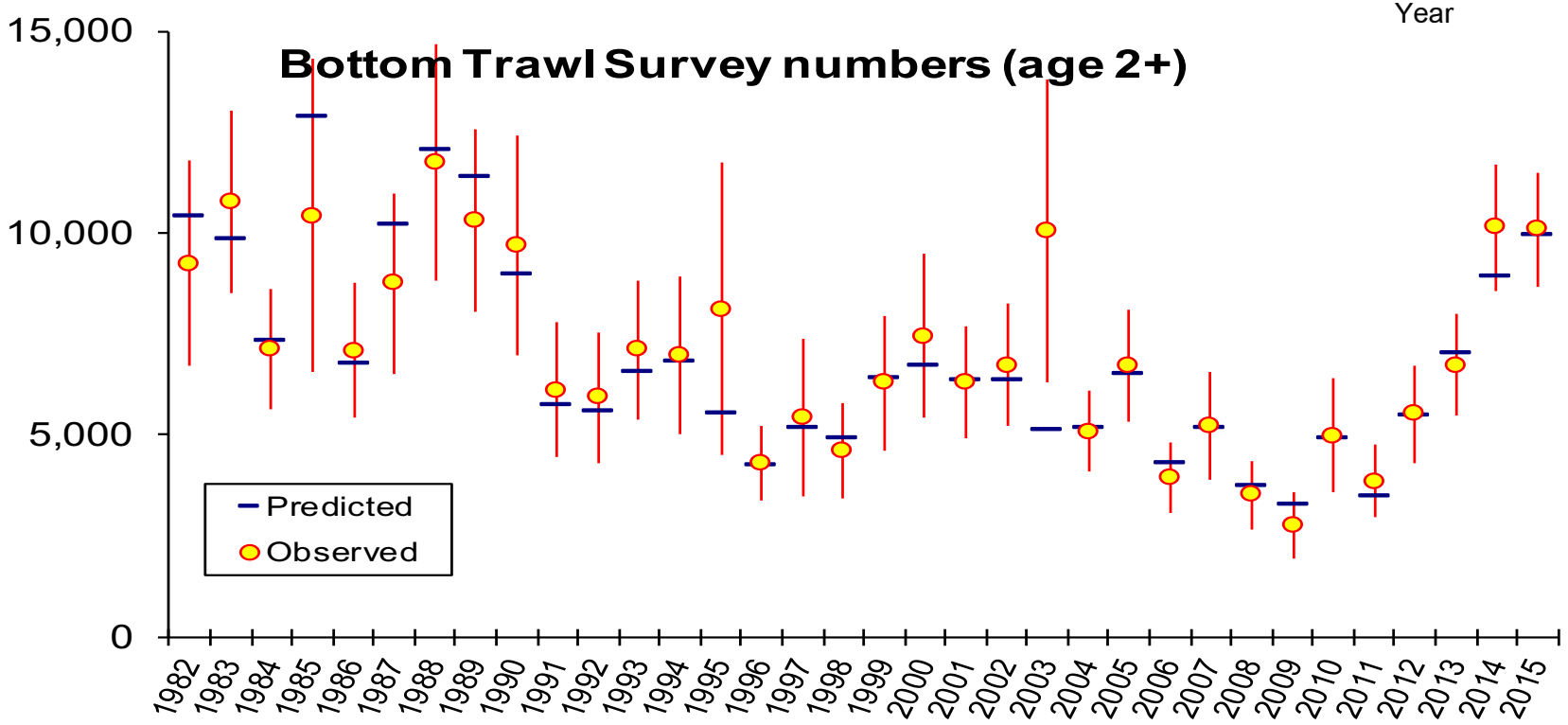
Fishery

Selectivity

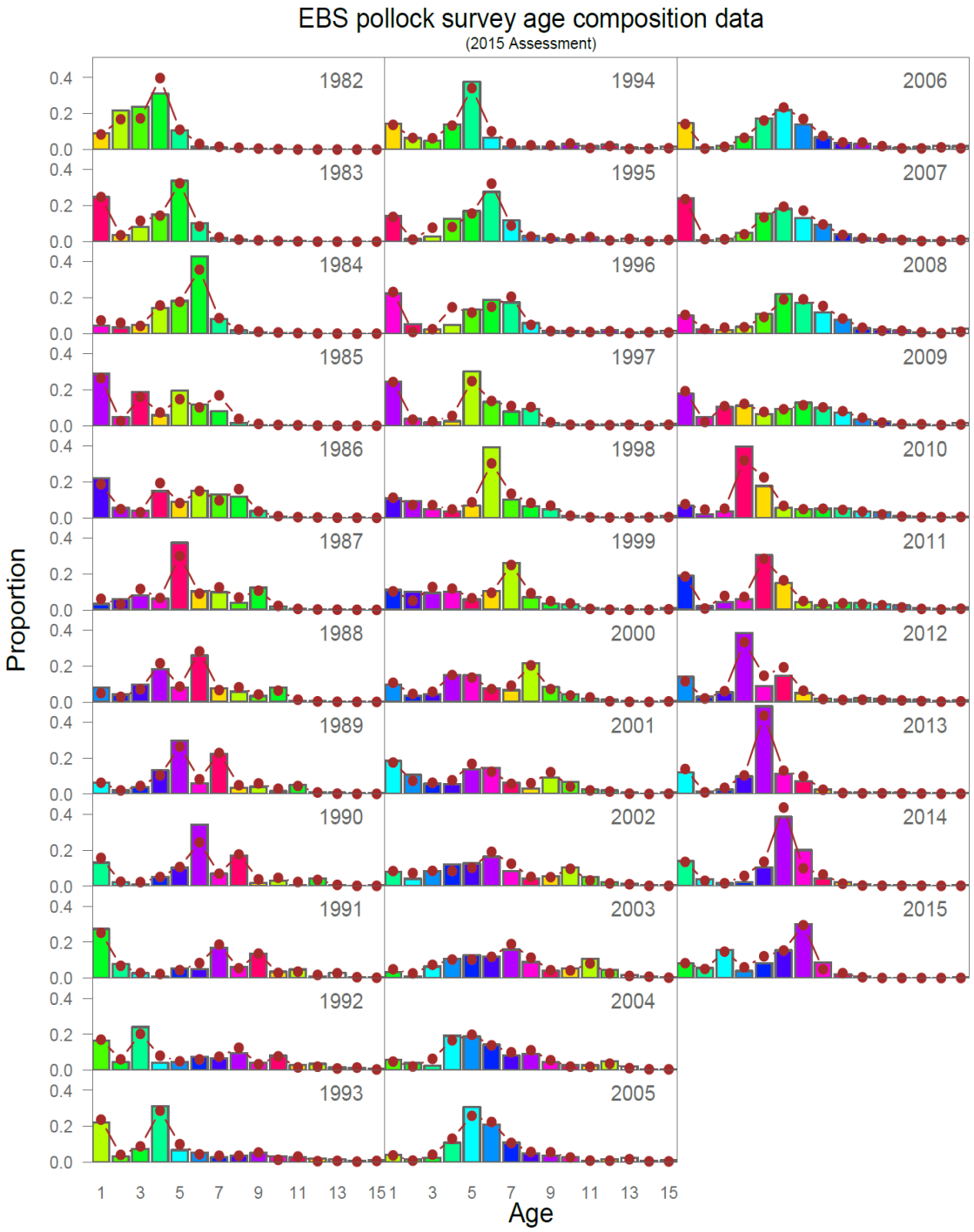


Fit to BTS indices



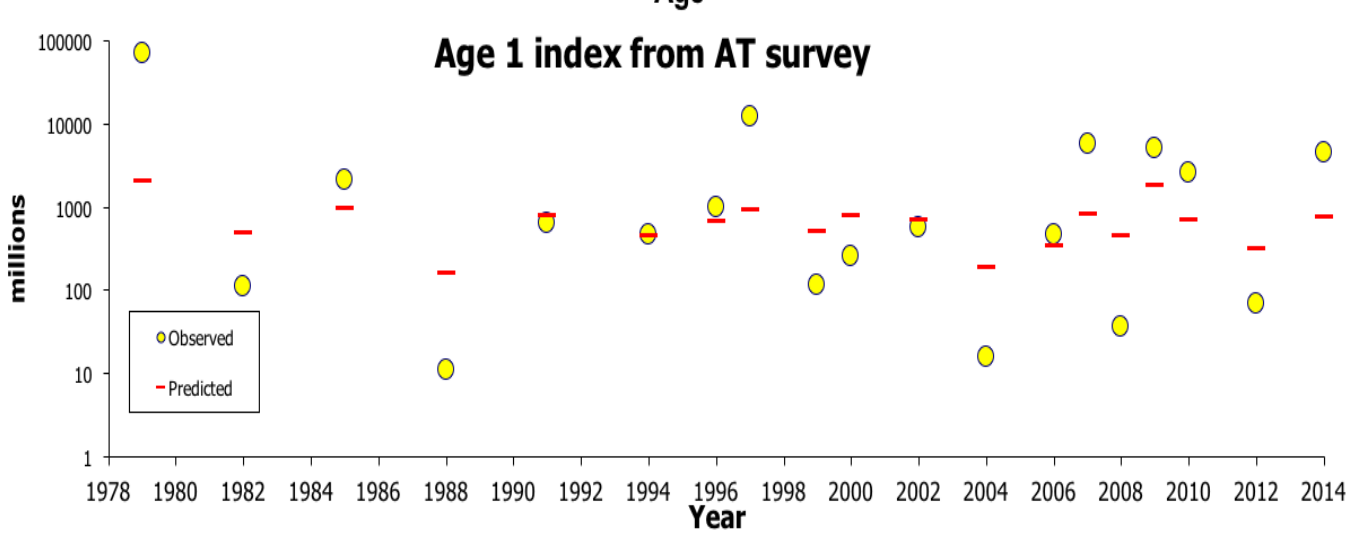


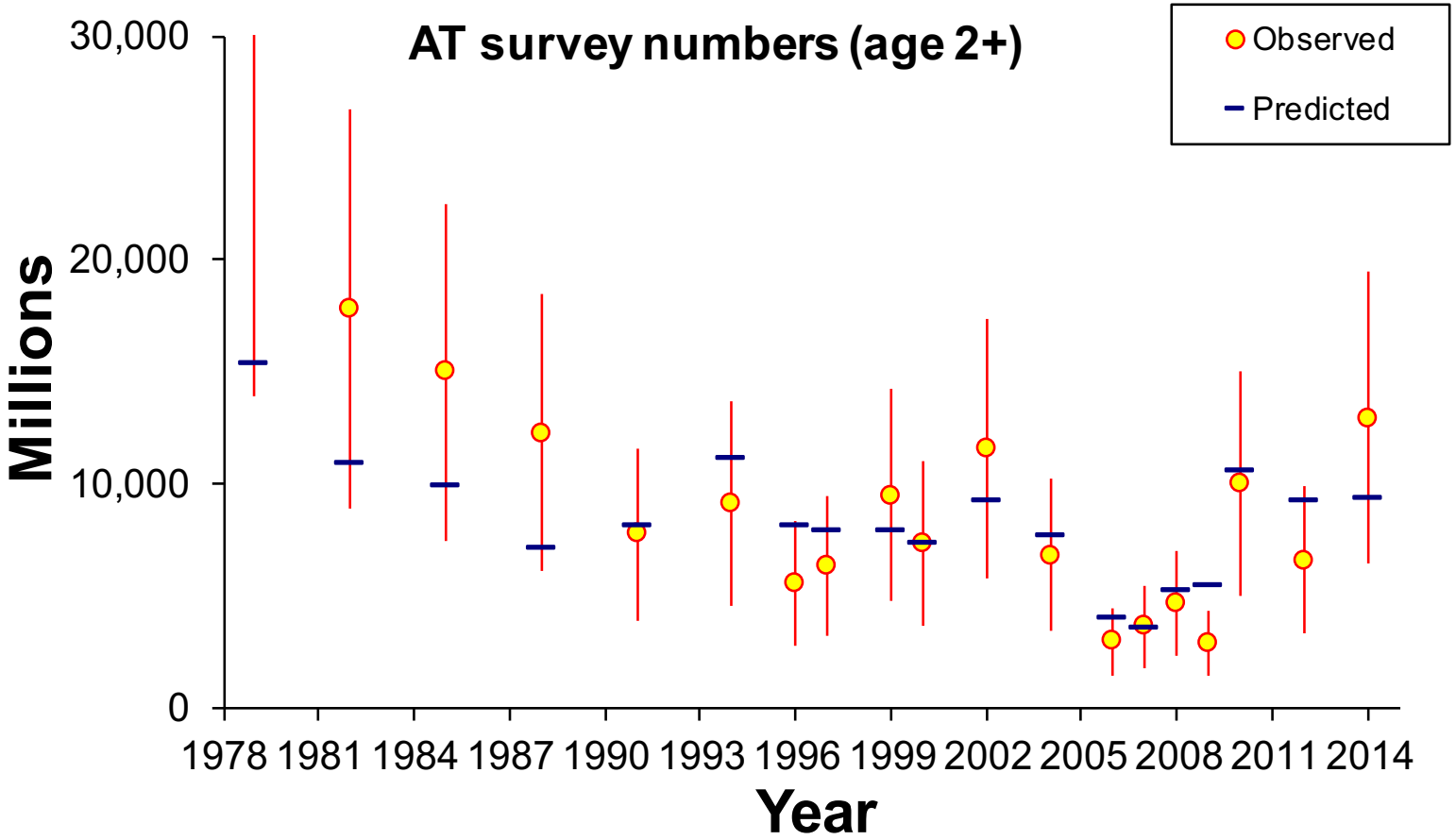
Survey age composition fits



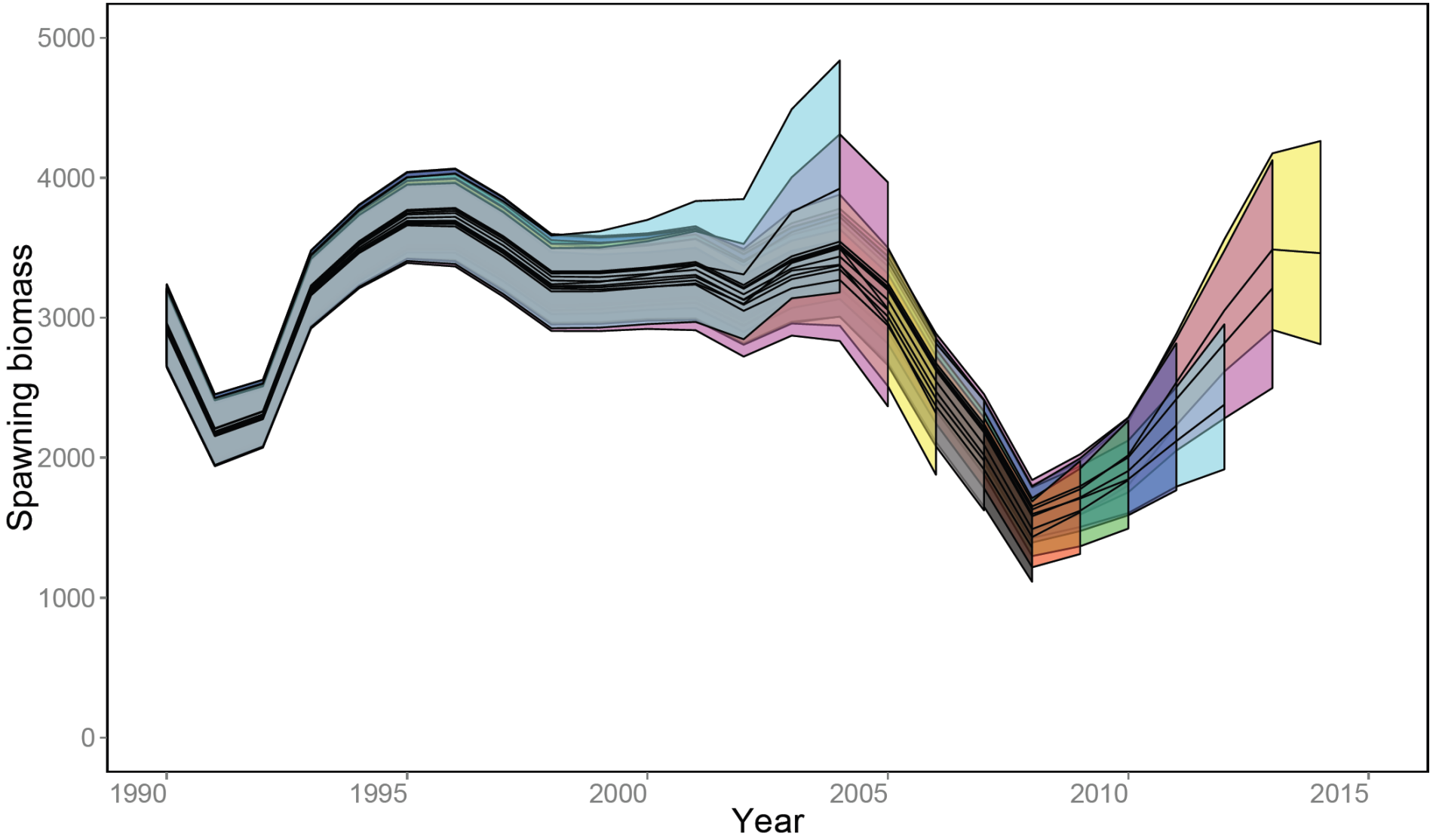
Acoustic data fits

Fit to AT index

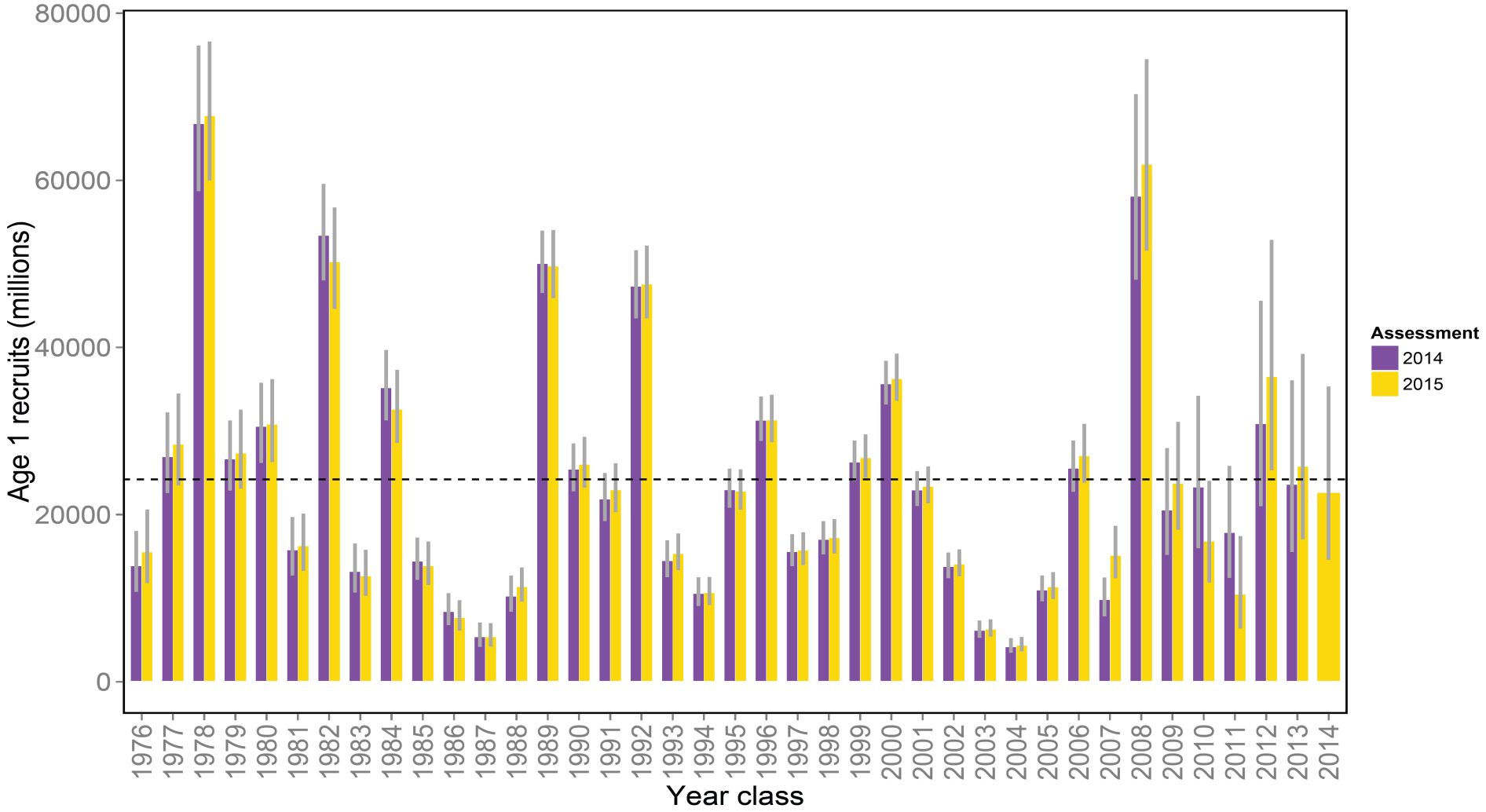




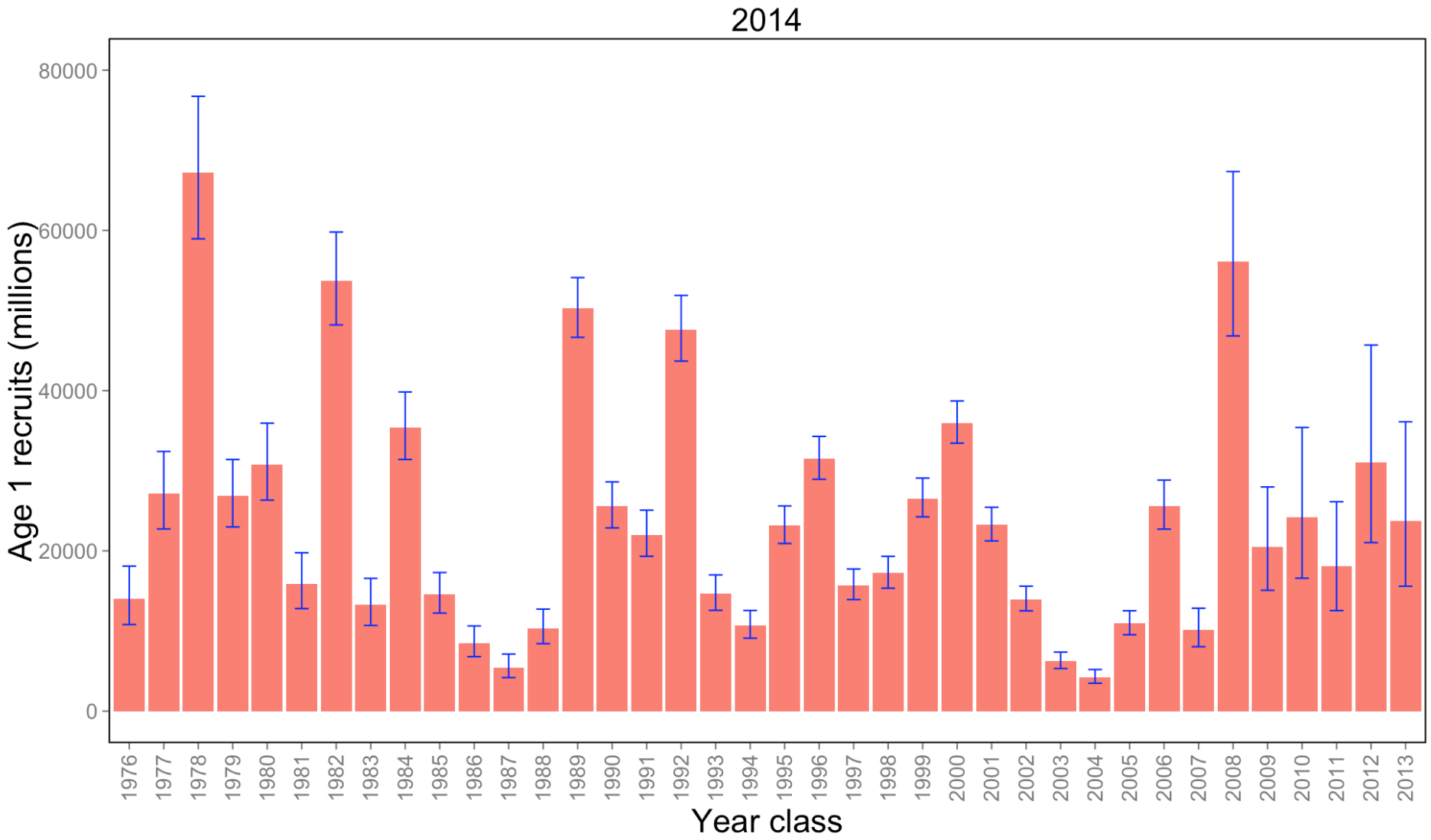
Retrospective patterns (kt)



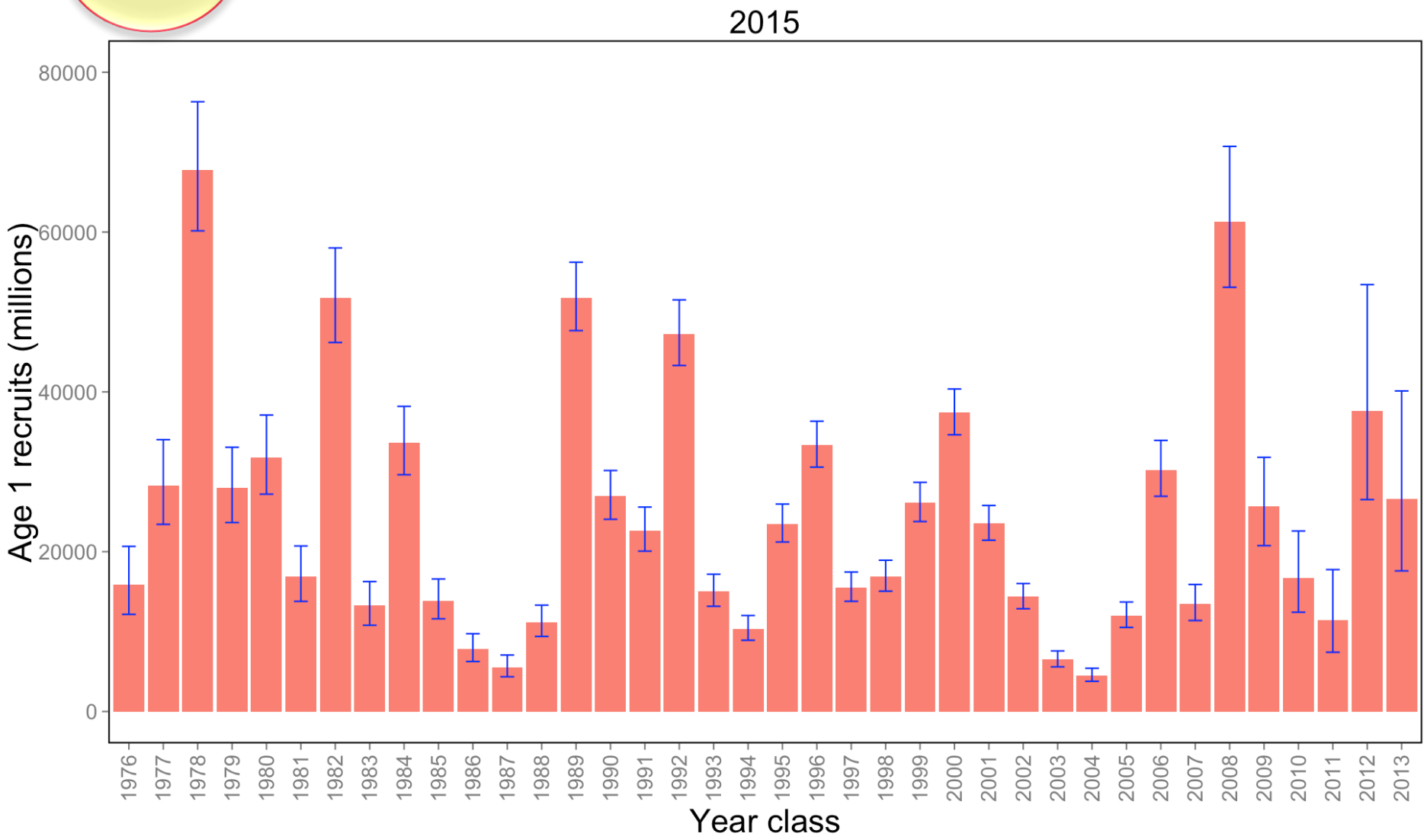
Year class estimates



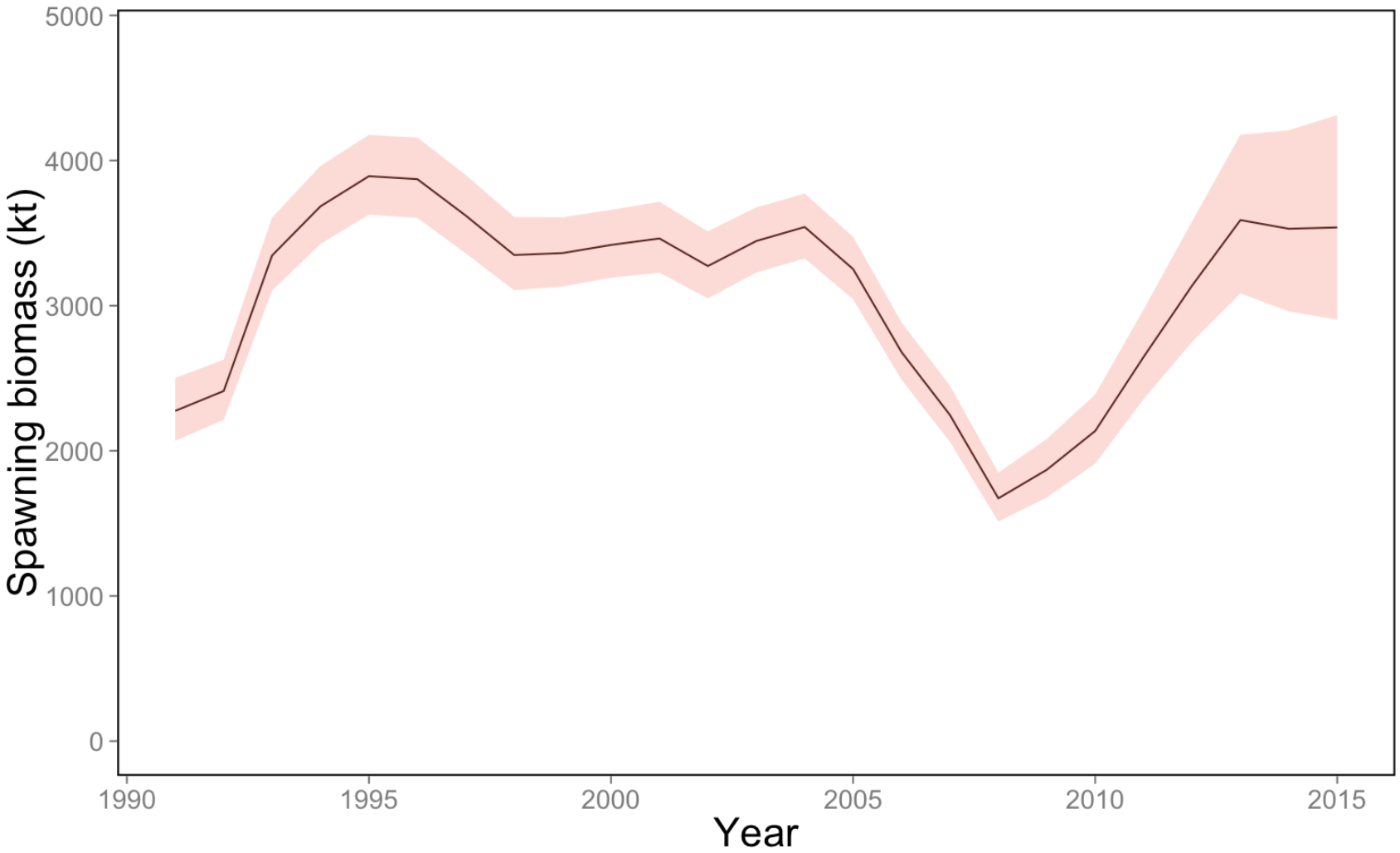
2014 model estimates of year class



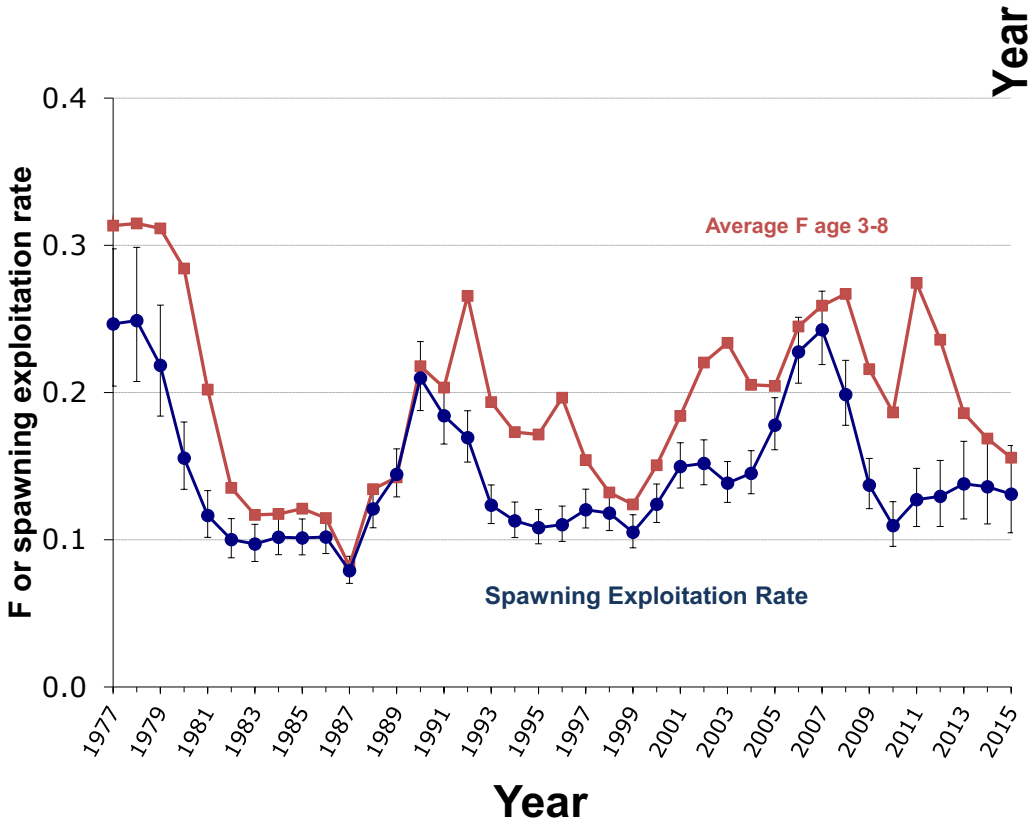
2015 model estimates of year class



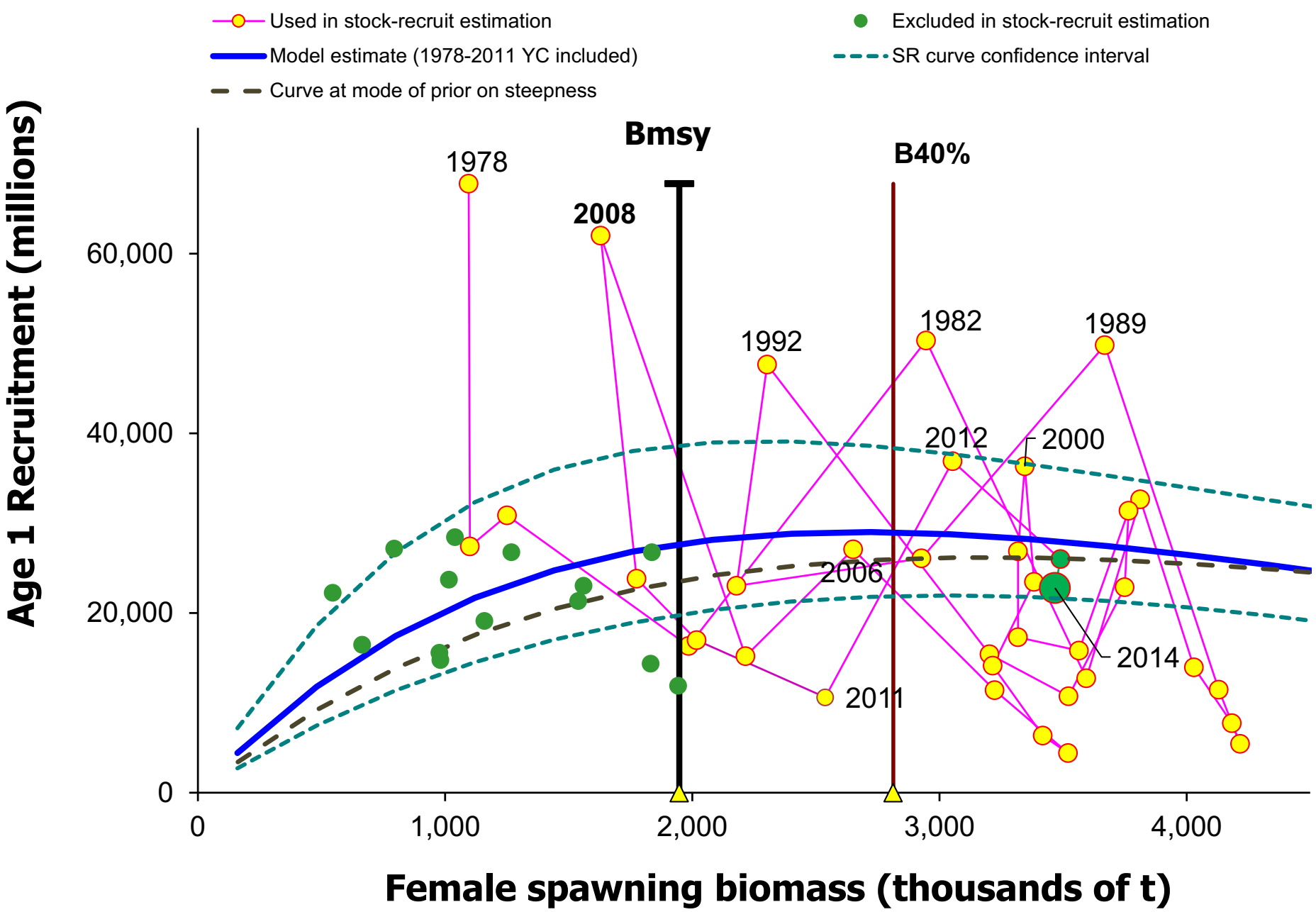
E. Bering Sea pollock spawning biomass



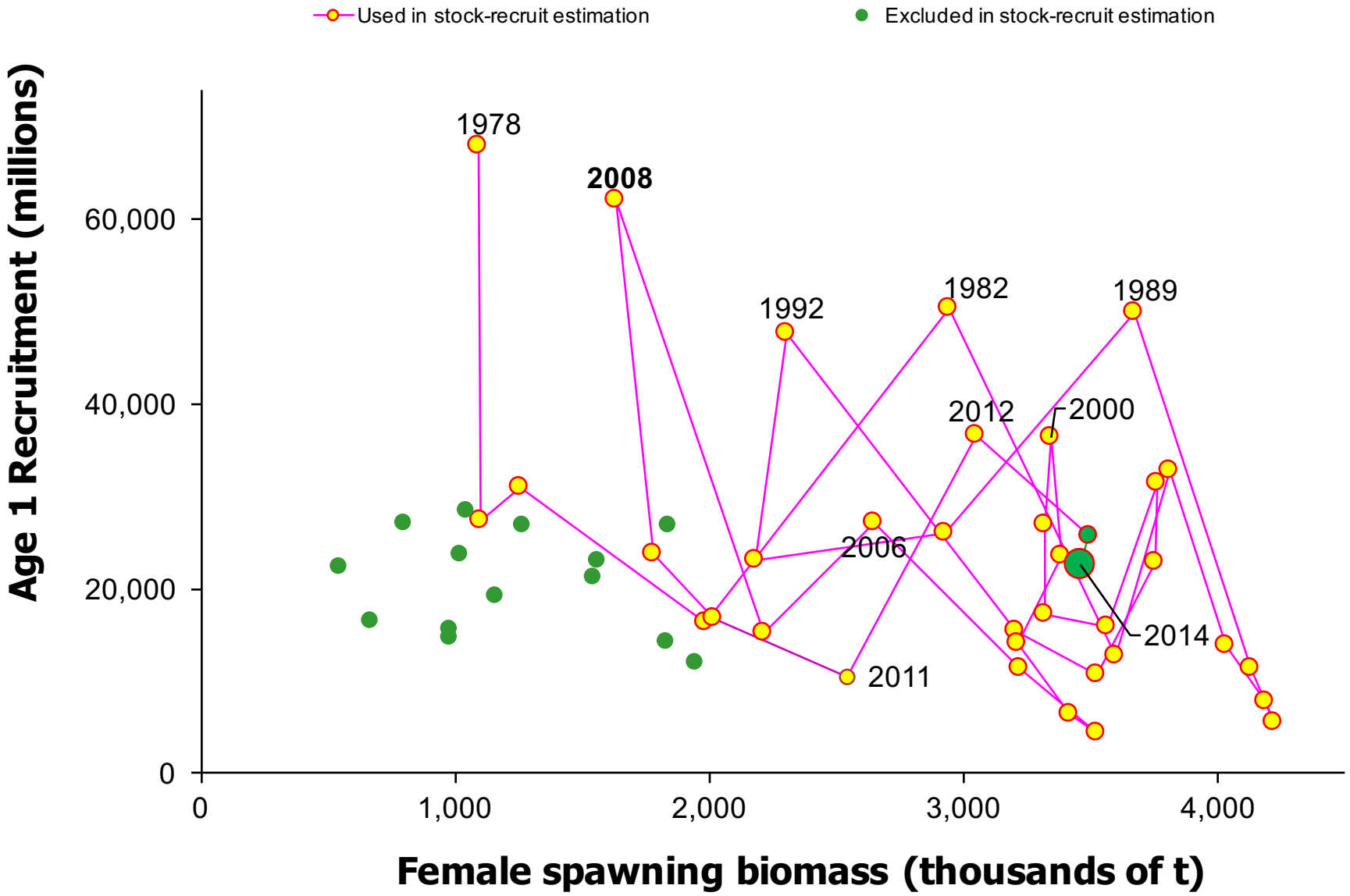
Fishing mortality



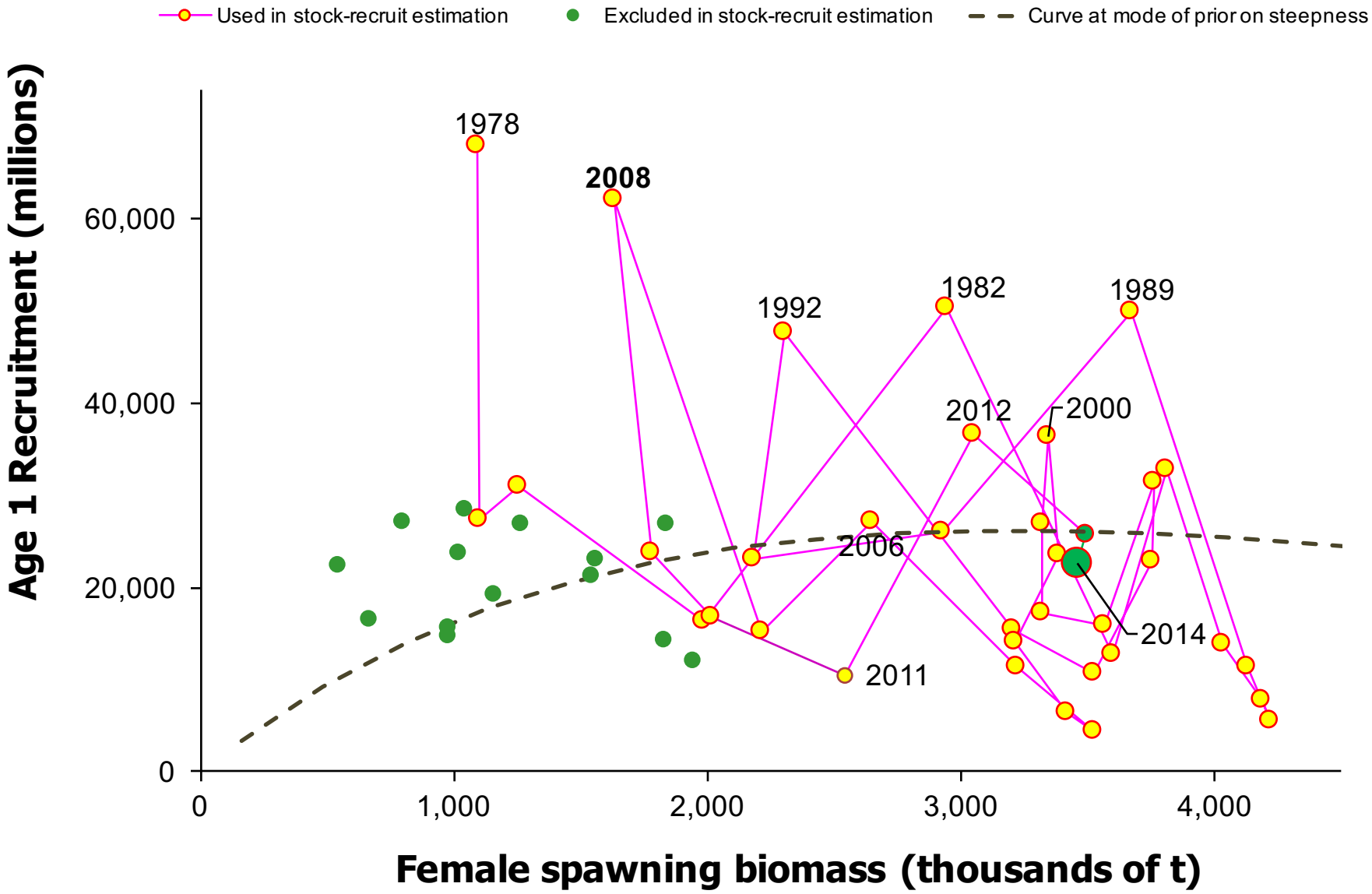
	Age								
	2	3	4	5	6	7	8	9	10
1964	0.01	0.03	0.16	0.17	0.17	0.17	0.16	0.16	0.15
1965	0.01	0.04	0.17	0.16	0.15	0.15	0.14	0.13	0.13
1966	0.01	0.05	0.15	0.14	0.14	0.13	0.12	0.12	0.12
1967	0.03	0.13	0.20	0.21	0.21	0.21	0.21	0.20	0.20
1968	0.03	0.11	0.22	0.21	0.21	0.20	0.20	0.20	0.19
1969	0.03	0.16	0.20	0.20	0.19	0.19	0.19	0.19	0.19
1970	0.06	0.22	0.22	0.24	0.24	0.26	0.28	0.29	0.36
1971	0.08	0.26	0.30	0.36	0.35	0.35	0.39	0.40	0.56
1972	0.13	0.34	0.39	0.39	0.38	0.38	0.42	0.44	0.55
1973	0.16	0.37	0.47	0.47	0.47	0.47	0.51	0.51	0.59
1974	0.22	0.48	0.48	0.48	0.48	0.48	0.52	0.53	0.53
1975	0.12	0.47	0.45	0.43	0.42	0.41	0.42	0.44	0.48
1976	0.09	0.36	0.42	0.40	0.38	0.38	0.38	0.38	0.40
1977	0.10	0.26	0.33	0.33	0.32	0.32	0.32	0.32	0.32
1978	0.09	0.28	0.32	0.33	0.32	0.32	0.32	0.33	0.33
1979	0.05	0.23	0.28	0.35	0.34	0.34	0.34	0.37	0.38
1980	0.02	0.14	0.26	0.32	0.33	0.33	0.32	0.34	0.41
1981	0.01	0.07	0.18	0.24	0.24	0.24	0.24	0.25	0.33
1982	0.01	0.03	0.11	0.17	0.17	0.16	0.16	0.18	0.26
1983	0.01	0.03	0.08	0.13	0.16	0.15	0.15	0.17	0.27
1984	0.01	0.02	0.08	0.15	0.15	0.15	0.15	0.16	0.24
1985	0.01	0.03	0.06	0.11	0.18	0.17	0.17	0.17	0.25
1986	0.01	0.03	0.08	0.10	0.16	0.16	0.15	0.17	0.20
1987	0.00	0.02	0.05	0.07	0.10	0.10	0.15	0.16	0.20
1988	0.01	0.08	0.08	0.14	0.14	0.19	0.17	0.18	0.17
1989	0.01	0.04	0.10	0.13	0.16	0.22	0.20	0.19	0.18
1990	0.01	0.04	0.18	0.26	0.26	0.27	0.29	0.27	0.24
1991	0.01	0.02	0.11	0.21	0.25	0.34	0.28	0.35	0.38
1992	0.01	0.06	0.09	0.18	0.33	0.44	0.50	0.52	0.51
1993	0.00	0.04	0.16	0.12	0.21	0.31	0.31	0.31	0.28
1994	0.00	0.01	0.09	0.24	0.21	0.25	0.24	0.23	0.23
1995	0.00	0.01	0.04	0.15	0.31	0.27	0.26	0.25	0.24
1996	0.01	0.01	0.02	0.07	0.24	0.40	0.44	0.39	0.35
1997	0.01	0.02	0.04	0.08	0.17	0.29	0.32	0.39	0.37
1998	0.00	0.02	0.04	0.09	0.19	0.19	0.26	0.32	0.32
1999	0.00	0.04	0.06	0.09	0.13	0.22	0.20	0.19	0.18
2000	0.00	0.02	0.09	0.14	0.14	0.23	0.28	0.22	0.20
2001	0.00	0.02	0.07	0.19	0.28	0.27	0.27	0.25	0.24
2002	0.00	0.02	0.08	0.18	0.36	0.35	0.34	0.31	0.26
2003	0.00	0.05	0.08	0.21	0.32	0.38	0.36	0.31	0.25
2004	0.00	0.02	0.16	0.18	0.24	0.32	0.31	0.27	0.24
2005	0.00	0.02	0.11	0.28	0.30	0.27	0.25	0.23	0.20
2006	0.00	0.05	0.13	0.27	0.37	0.34	0.31	0.28	0.25
2007	0.00	0.05	0.13	0.27	0.41	0.37	0.32	0.29	0.27
2008	0.00	0.03	0.12	0.26	0.43	0.40	0.36	0.34	0.30
2009	0.00	0.02	0.11	0.17	0.31	0.34	0.34	0.35	0.35
2010	0.00	0.01	0.14	0.20	0.22	0.26	0.29	0.28	0.27
2011	0.00	0.01	0.06	0.36	0.43	0.40	0.38	0.36	0.35
2012	0.00	0.02	0.10	0.11	0.38	0.41	0.39	0.37	0.35
2013	0.00	0.02	0.09	0.15	0.17	0.27	0.40	0.40	0.42
2014	0.00	0.01	0.07	0.17	0.19	0.29	0.28	0.35	0.35
2015	0.00	0.01	0.07	0.19	0.19	0.24	0.24	0.34	0.34
5-yr Aver	**0.00**	**0.02**	**0.08**	**0.20**	**0.27**	**0.32**	**0.34**	**0.37**	**0.36**
5-yr Max	**0.00**	**0.02**	**0.10**	**0.36**	**0.43**	**0.41**	**0.40**	**0.40**	**0.42**
5-yr Min	**0.00**	**0.01**	**0.06**	**0.11**	**0.17**	**0.24**	**0.24**	**0.34**	**0.34**


Used in stock-recruit estimation
Excluded in stock-recruit estimation
Model estimate (1978-2011 YC included)
SR curve confidence interval
Curve at mode of prior on steepness
Bmsy
B40%
1978
2008
1992
1982
1989
2012
2000
2006
2014
2011
60,000
40,000
20,000
0
0
1,000
2,000
3,000
4,000
Age 1 Recruitment (millions)
Female spawning biomass (thousands of t)

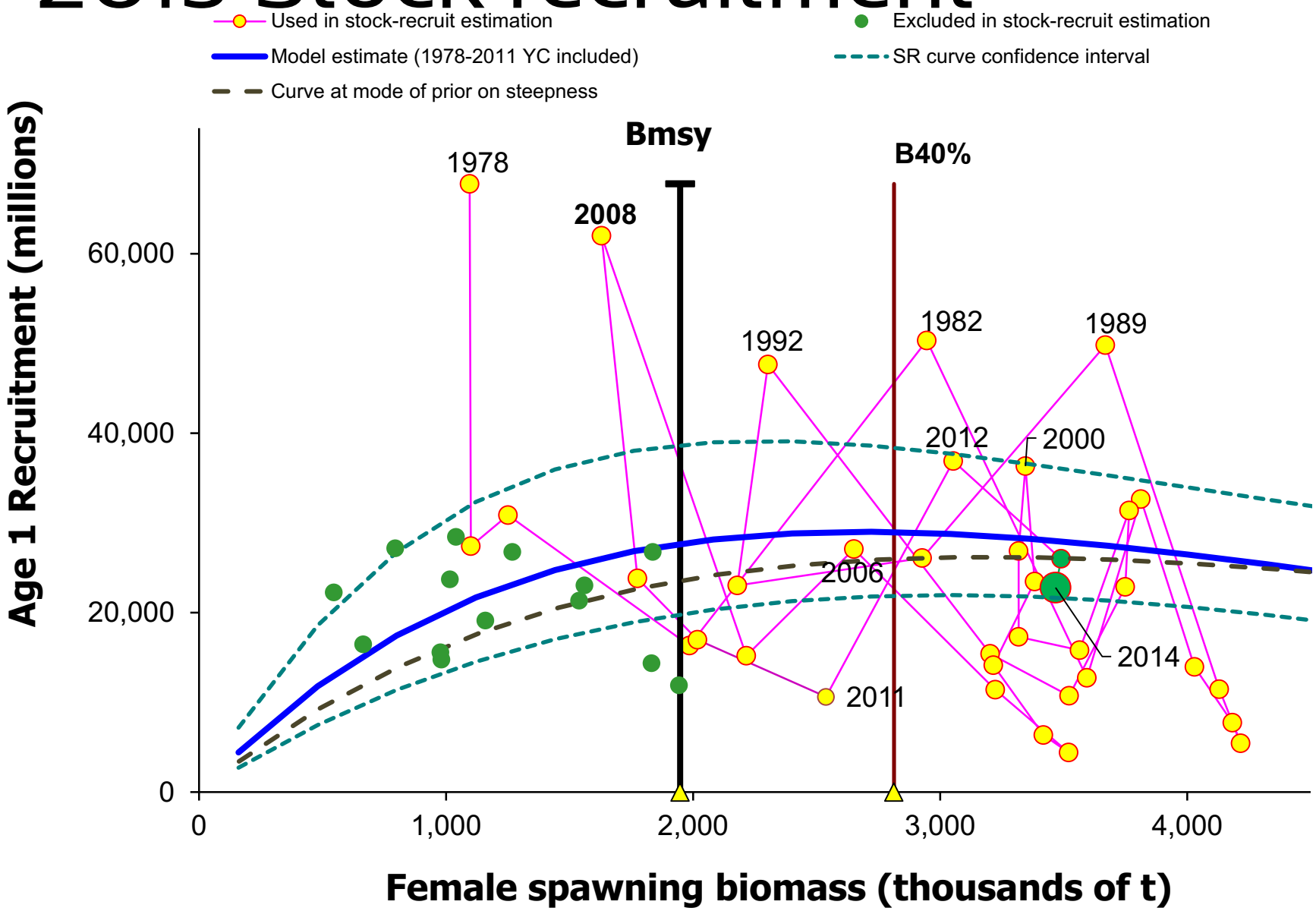
2015 Stock recruitment

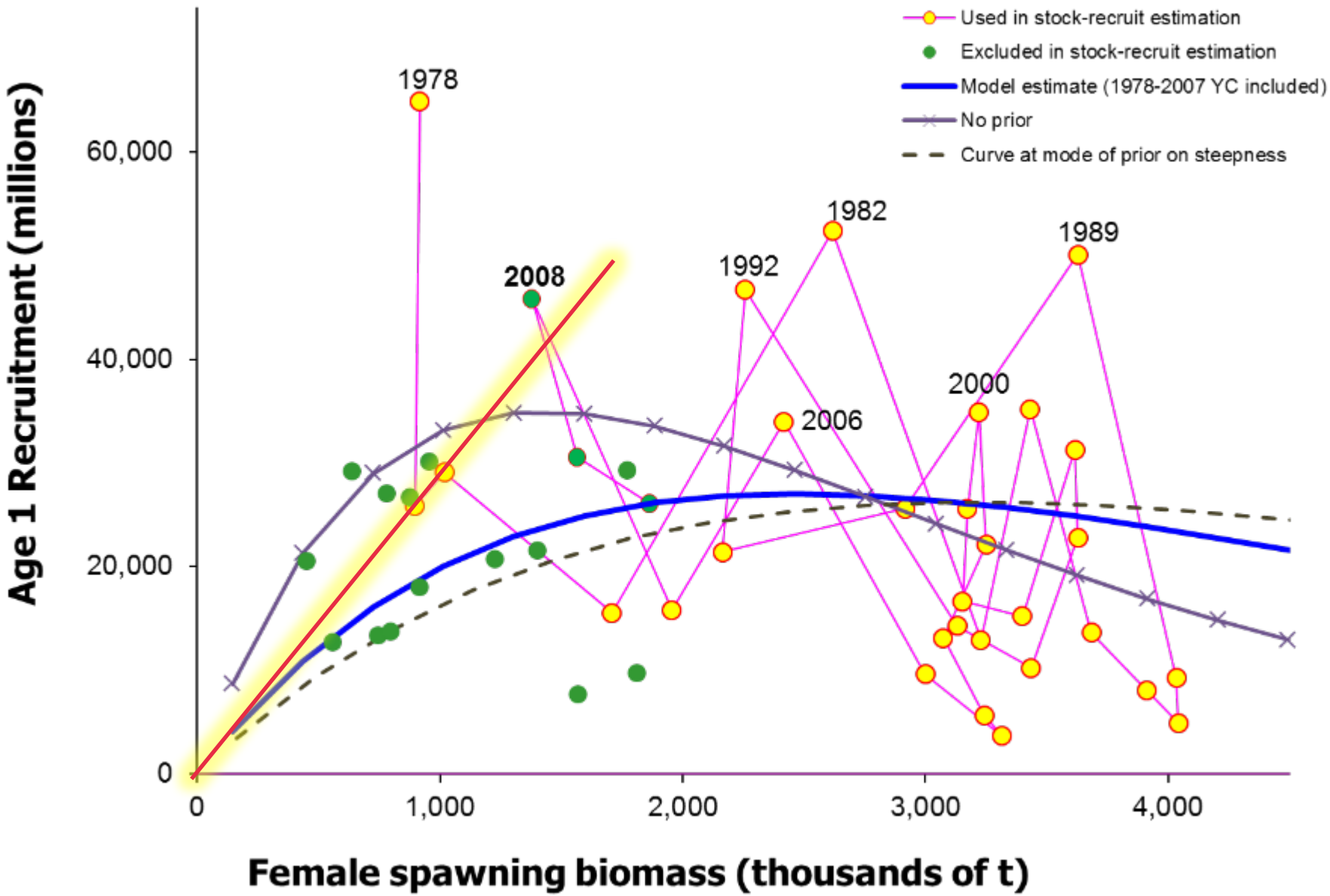


2015 Stock recruitment

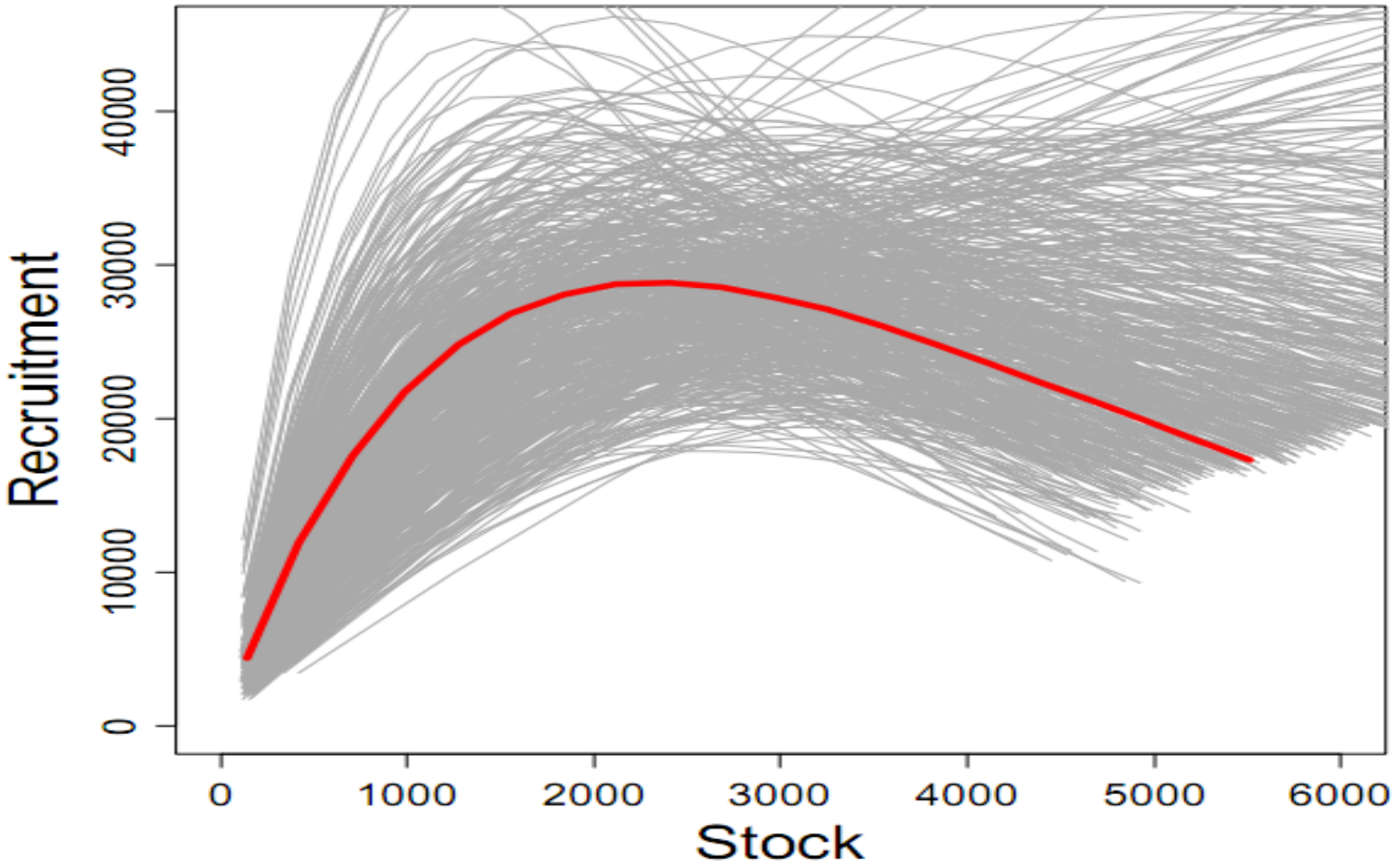


2015 Stock recruitment




Used in stock-recruit estimation
Excluded in stock-recruit estimation
Model estimate (1978-2007 YC included)
No prior
Curve at mode of prior on steepness
1978
2008
1992
1982
1989
2000
2006
60,000
40,000
20,000
0
0
1,000
2,000
3,000
4,000
Age 1 Recruitment (millions)
Female spawning biomass (thousands of t)

Posterior—EBS pollock



Tier 1 ABC calculation

Step 1: Estimate the stock productivity

- Function of stock-recruitment curve, maturity, growth, mortality
- Done within integrated model

Step 2: Estimate F_{msy} and uncertainty of F_{msy}

- Requires mean selectivity, wt-at-age in fishery

Step 3: Compute biomass and corresponding harvest rate

- Selected "fishable biomass" to provide smoother transition

The arithmatic

ABC = uBA

u = harmonic mean harvest rate

B = Median biomass (fishable)

A = adjustment factor
(if Tier 1b; i.e., below B_{msy})

Why ABC projections can change

Biological and estimation effects

- Changes in mean body mass-at-age
- Changes in selectivity-at-age patterns
- Changes in estimated numbers-at-age

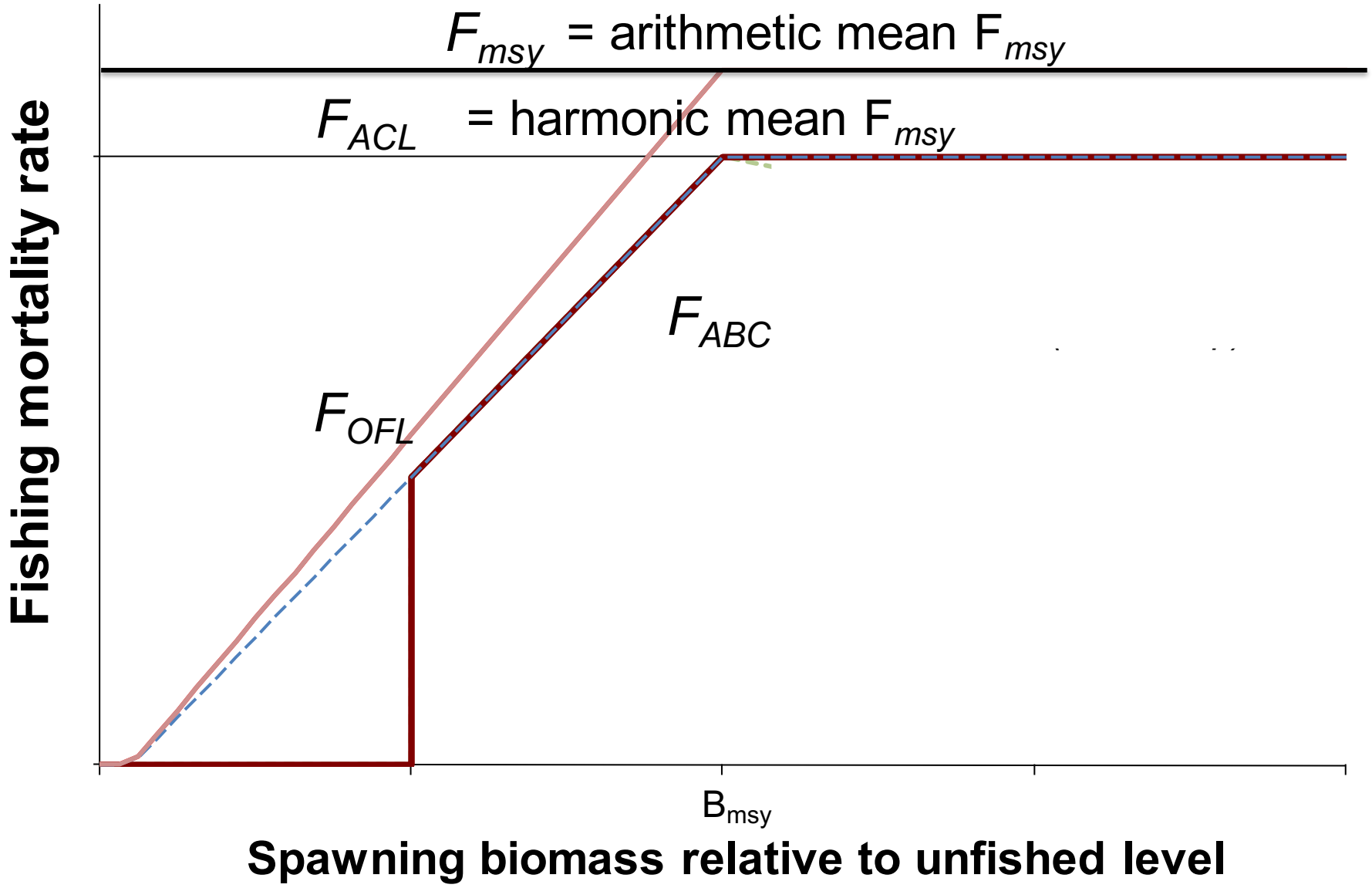
Harvest control rule

- Variable rate to promote rebuilding
  - Downside is higher variability in quotas as stock drops below Bmsy

Projecting ABC (Tier 1)

What is the “best” estimate of selectivity?

What is the impact of using uncertainty in fishery mean weights at age?


F_{msy} = arithmetic mean F_{msy}
F_{ACL} = harmonic mean F_{msy}
F_{ABC}
F_{OFL}
Fishing mortality rate
B_{msy}
Spawning biomass relative to unfished level

Tier 1 based on decision theoretic risk aversion

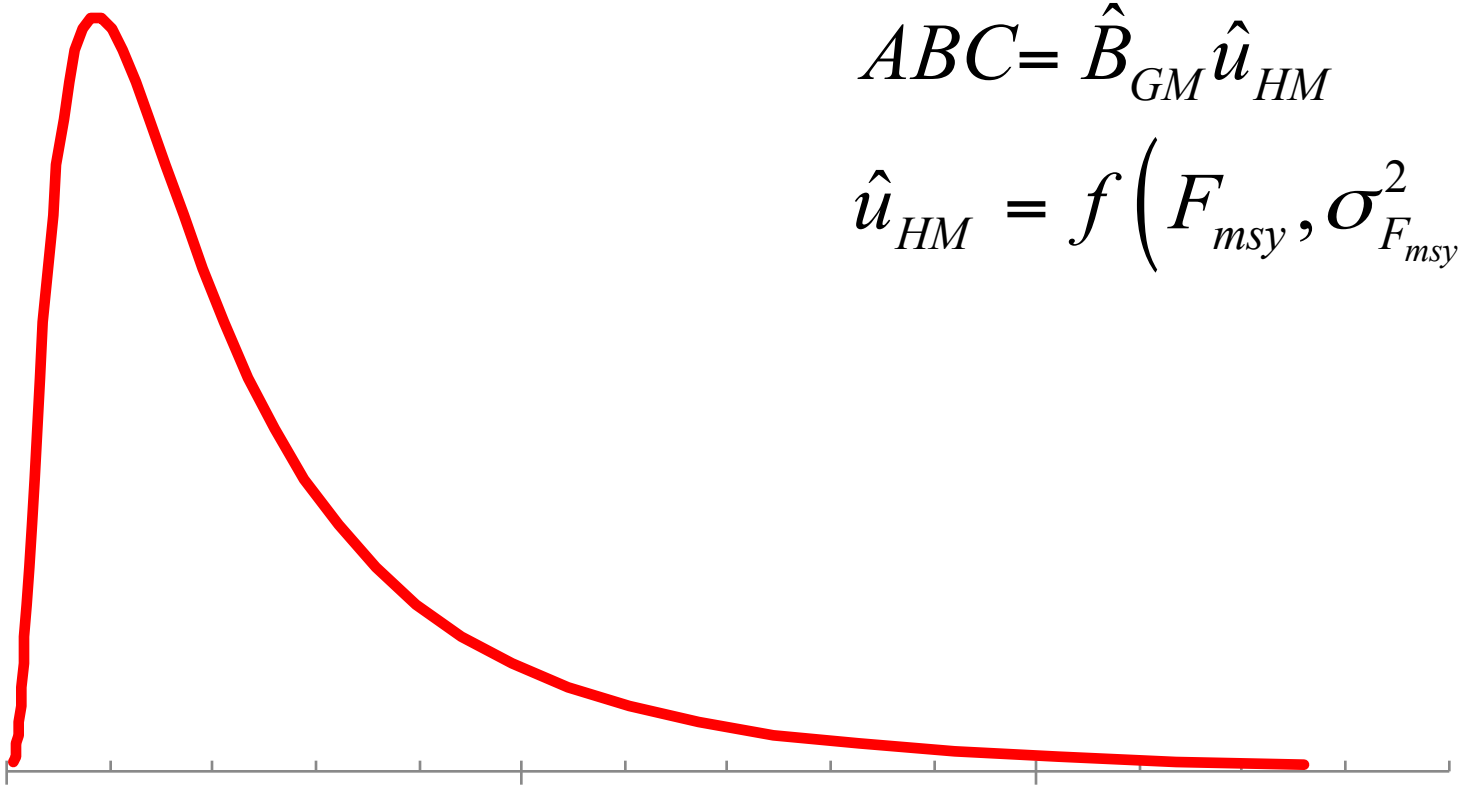
- Criteria
  - Stock-recruitment relationship affects catch limits
  - **Uncertainty** of F_{msy} estimate must be "reliable"
  - Given that uncertainty, formally risk-averse approach is to apply harmonic mean of F_{msy}
    - Thompson 1996
- Advice on how to determine "reliable" unclear

PDF of F_{msy} …

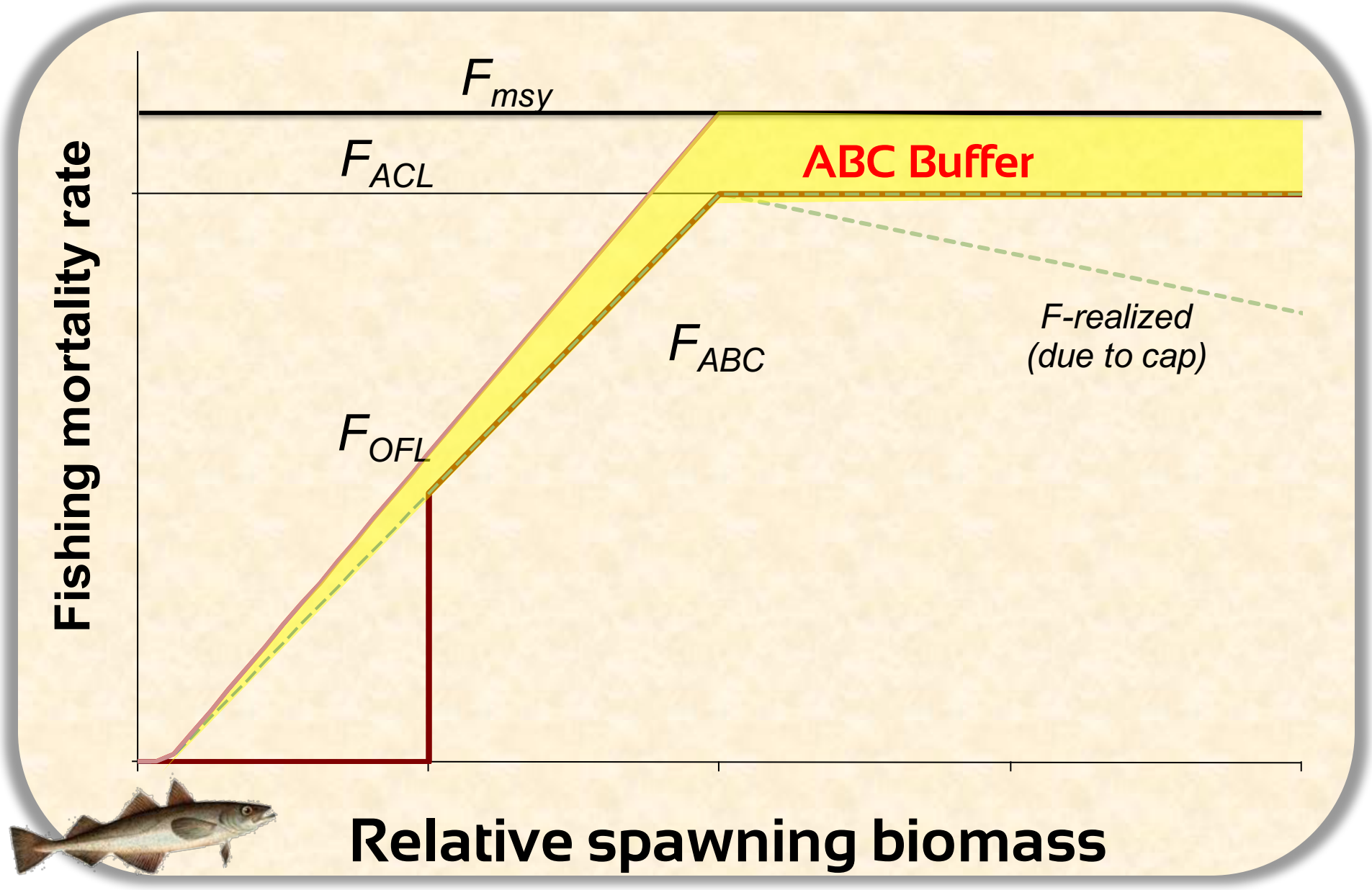
For a given year and $B \geq B_{msy}$:

$$ABC = \hat{B}_{GM}\hat{u}_{HM}$$

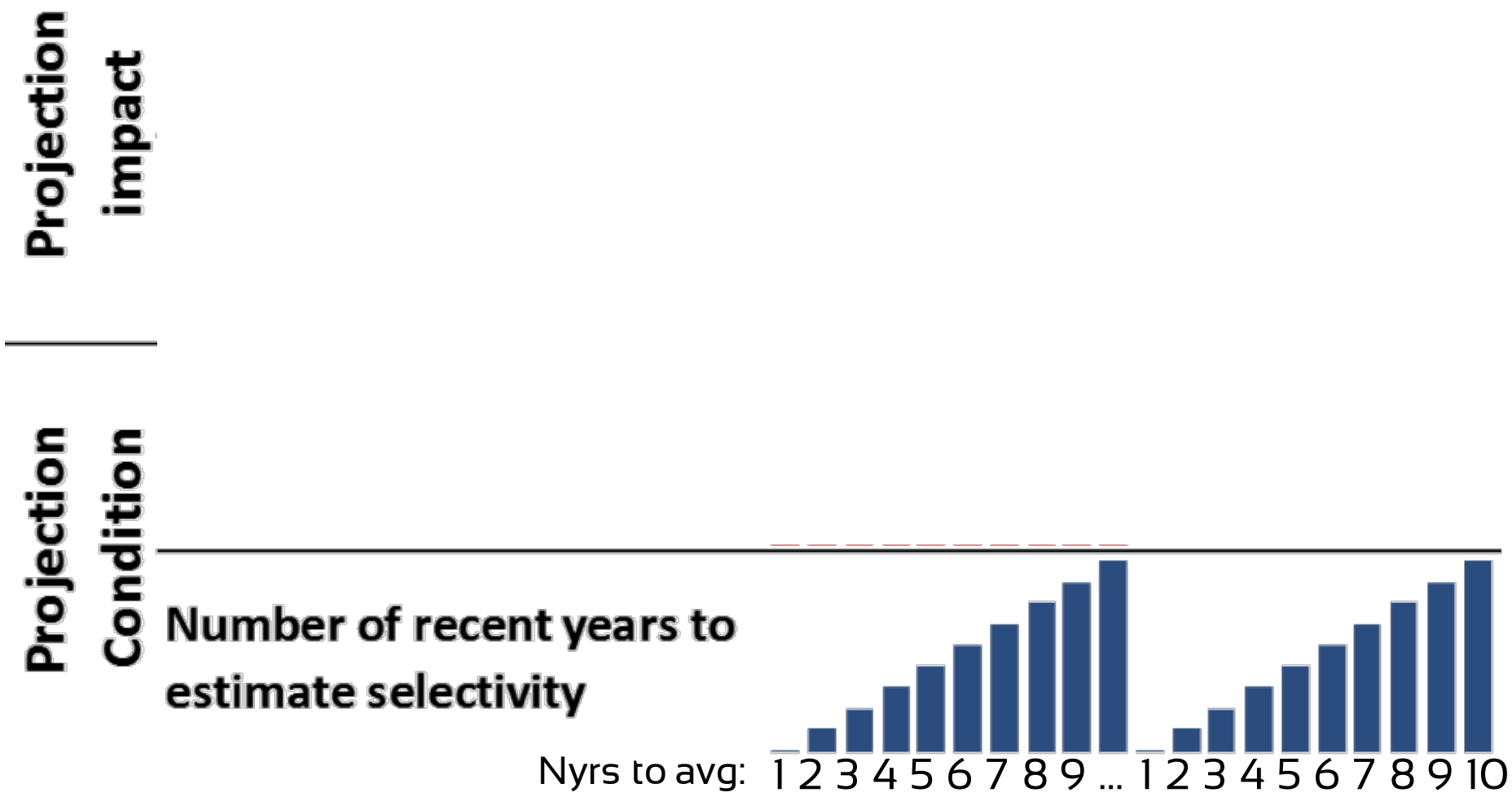
$$\hat{u}_{HM} = f\left(F_{msy}, \sigma^2_{F_{msy}}\right)$$



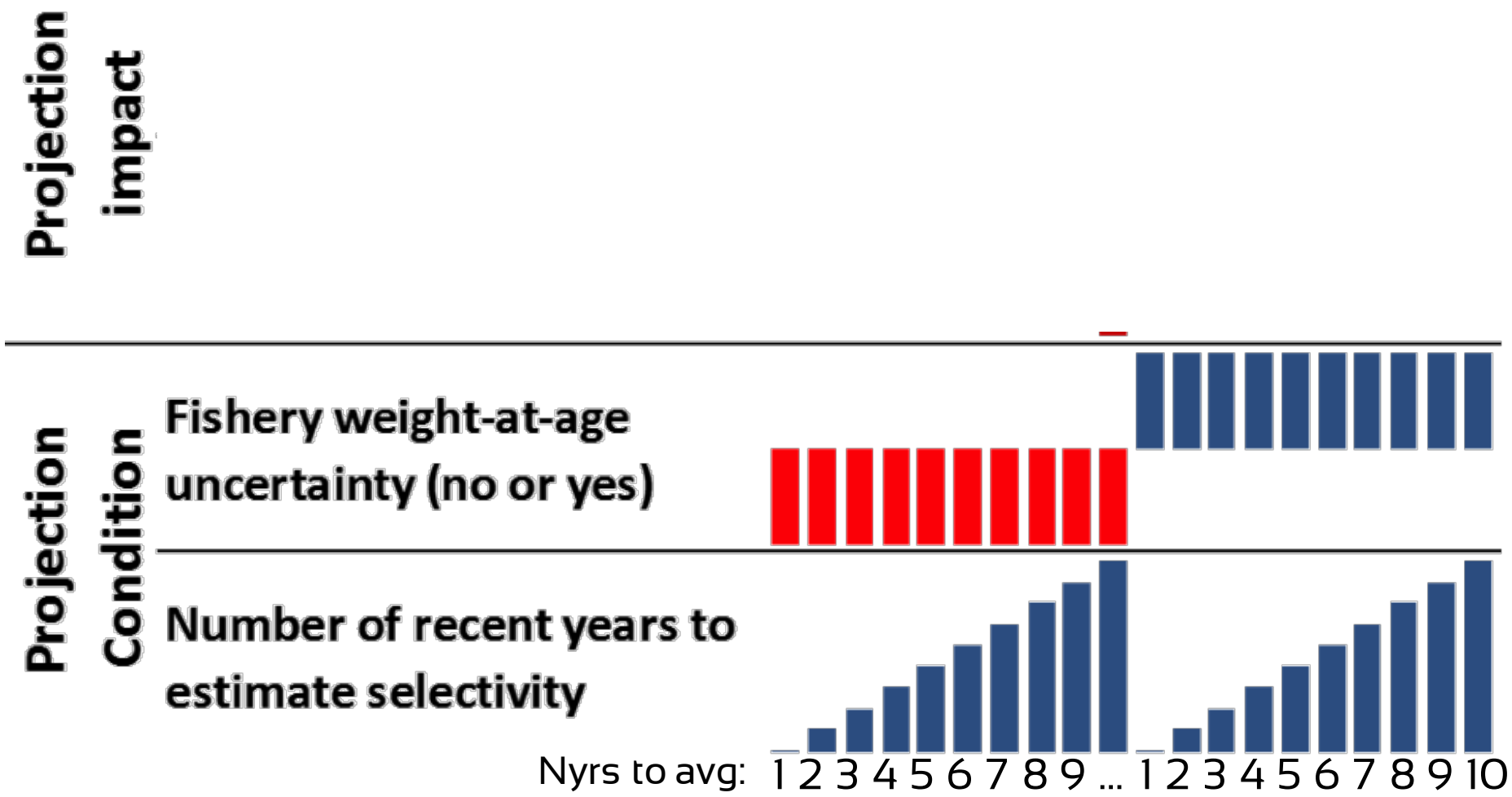
Setting catch limits…



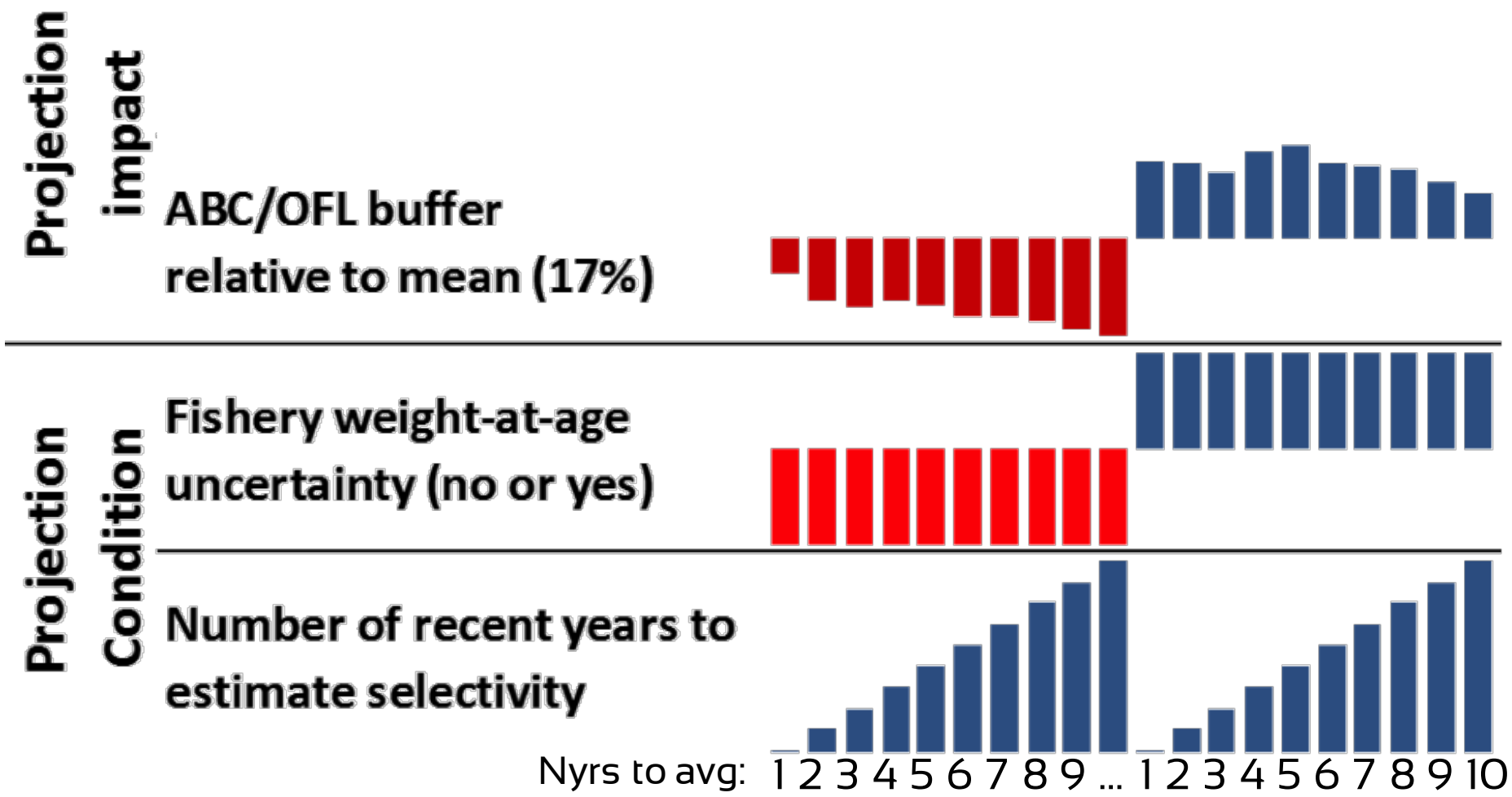
Projecting ABC (Tier 1)



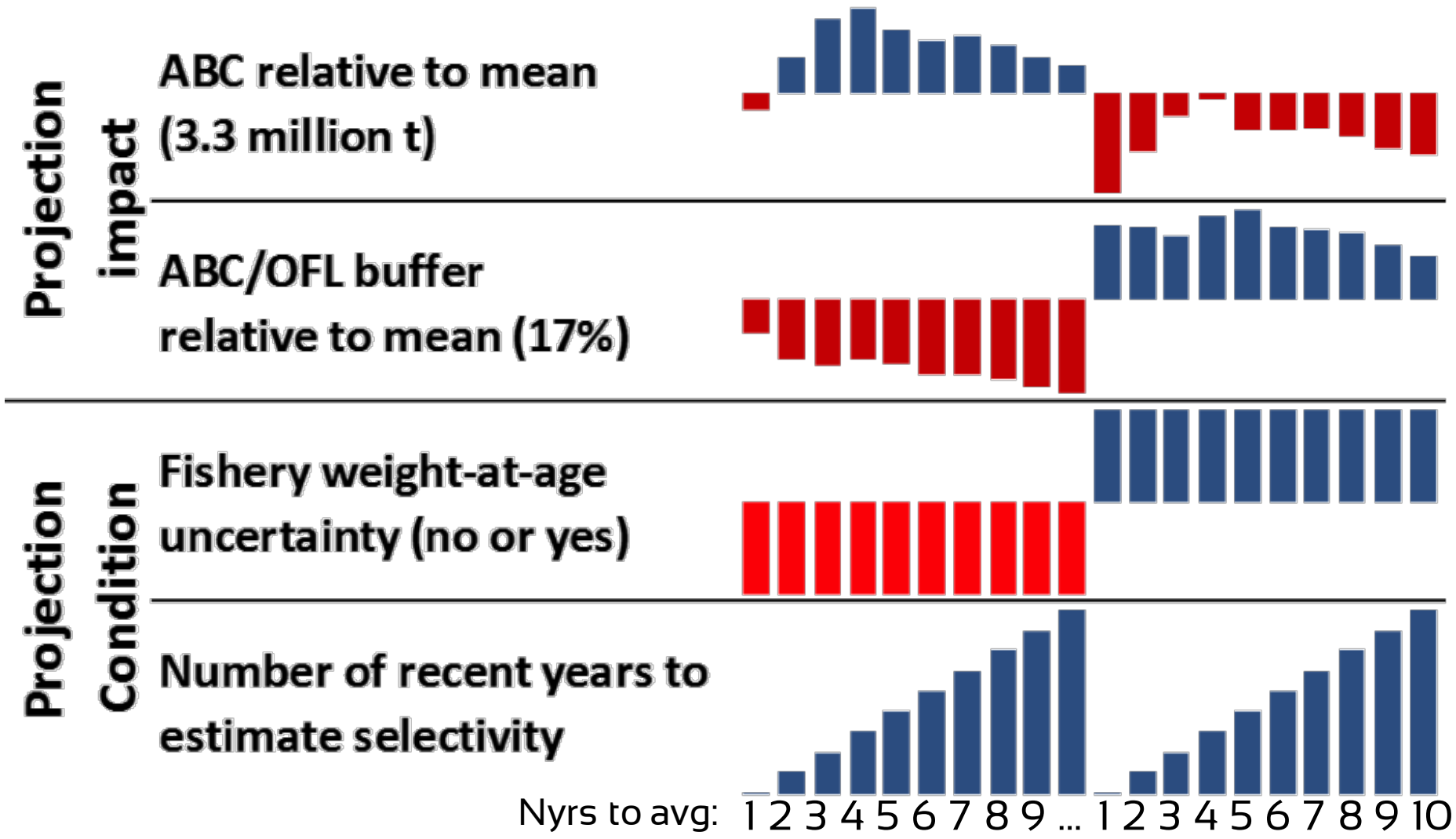
Projecting ABC (Tier 1)



Projecting ABC (Tier 1)

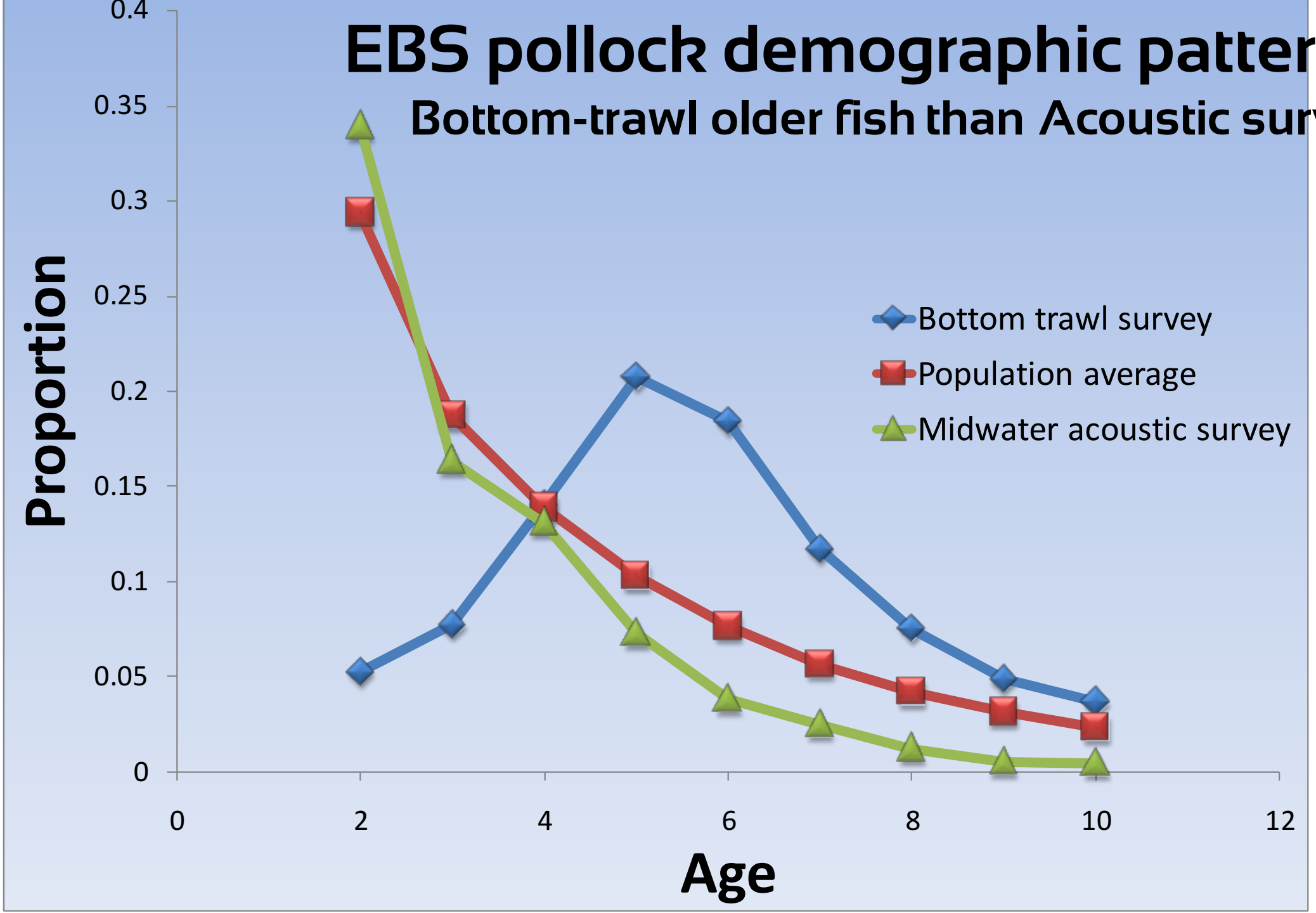


Projecting ABC (Tier 1)

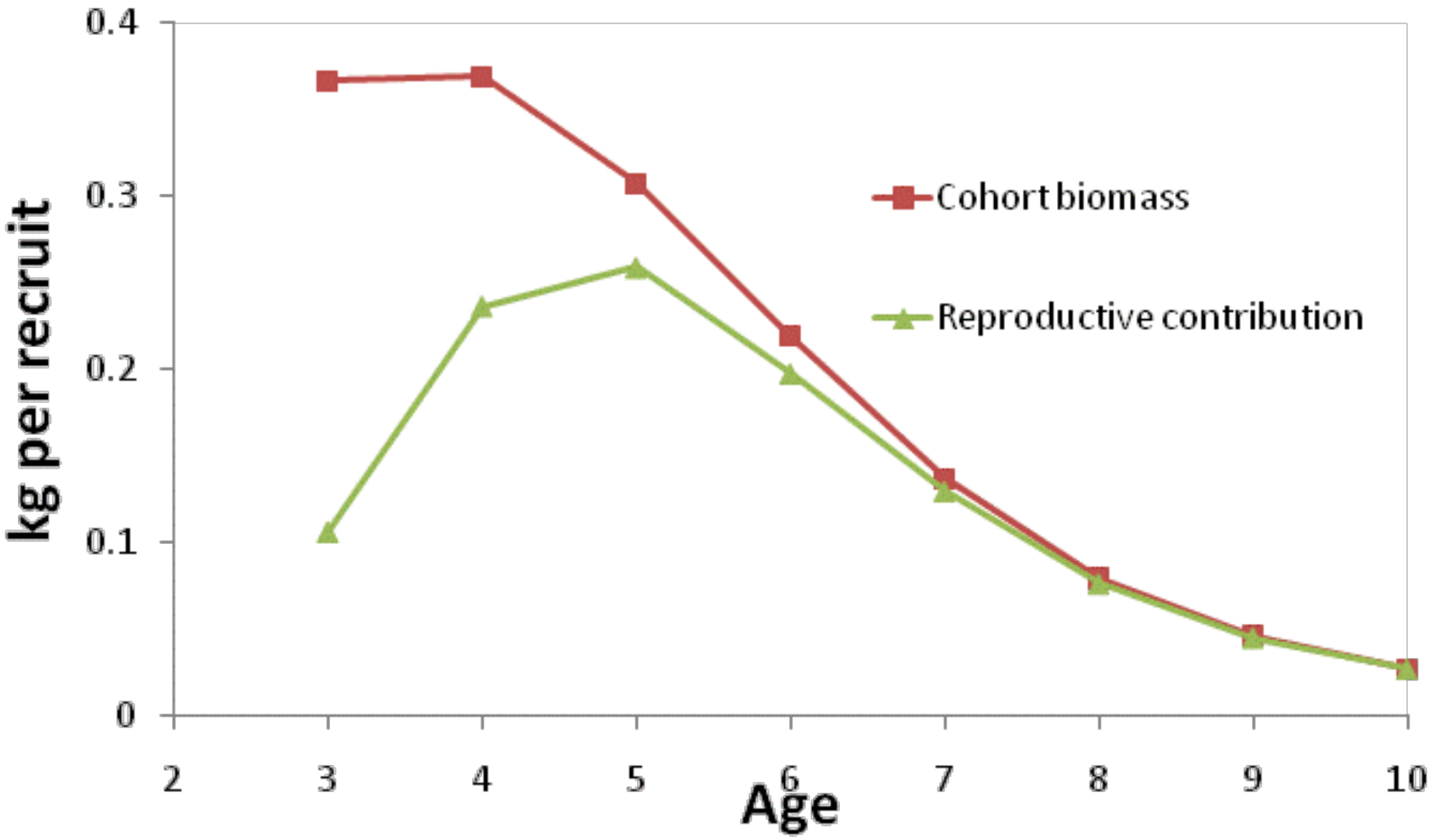


EBS pollock demographic patterns

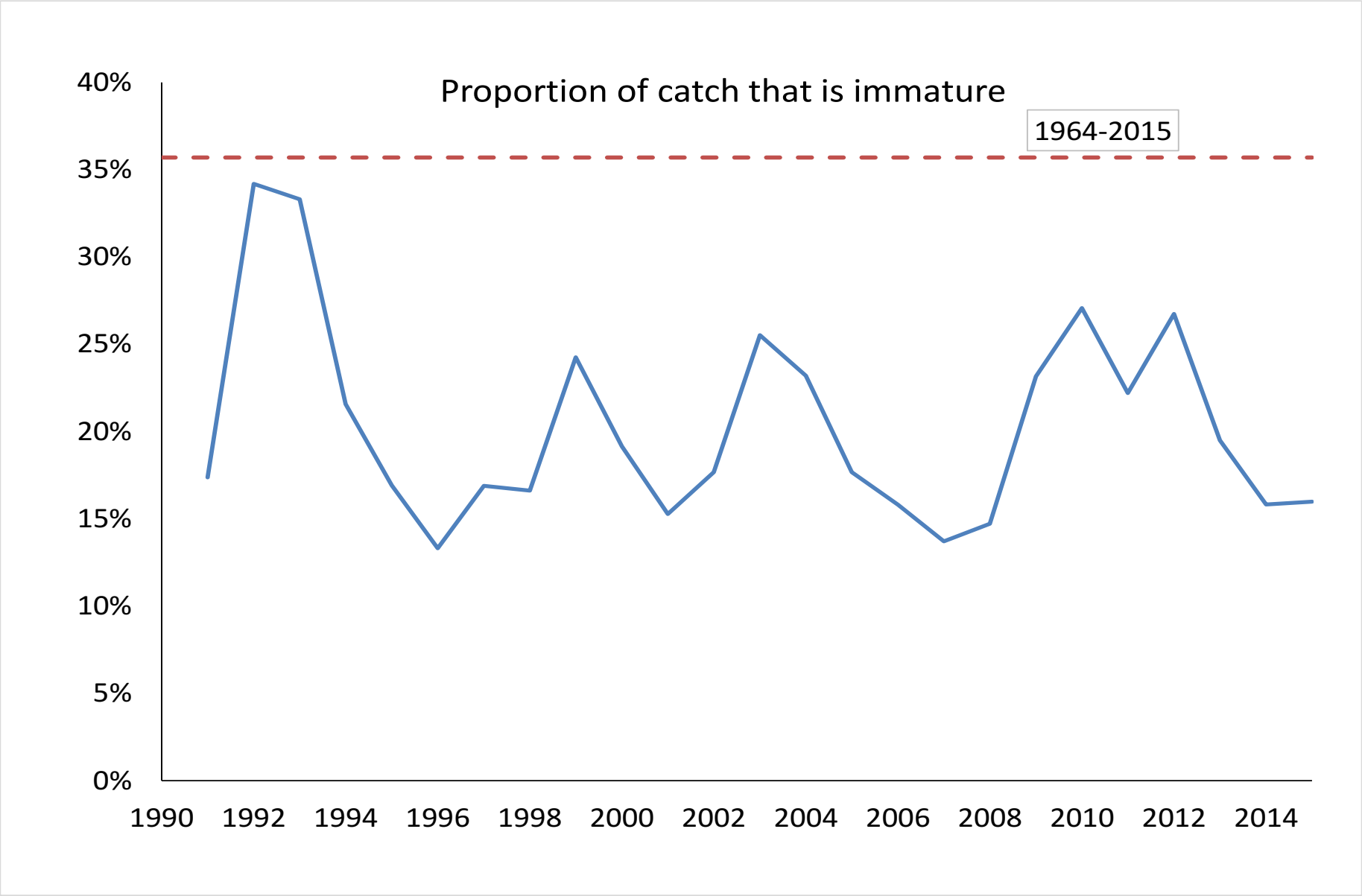
Bottom-trawl older fish than Acoustic survey



Implications of catching younger pollock

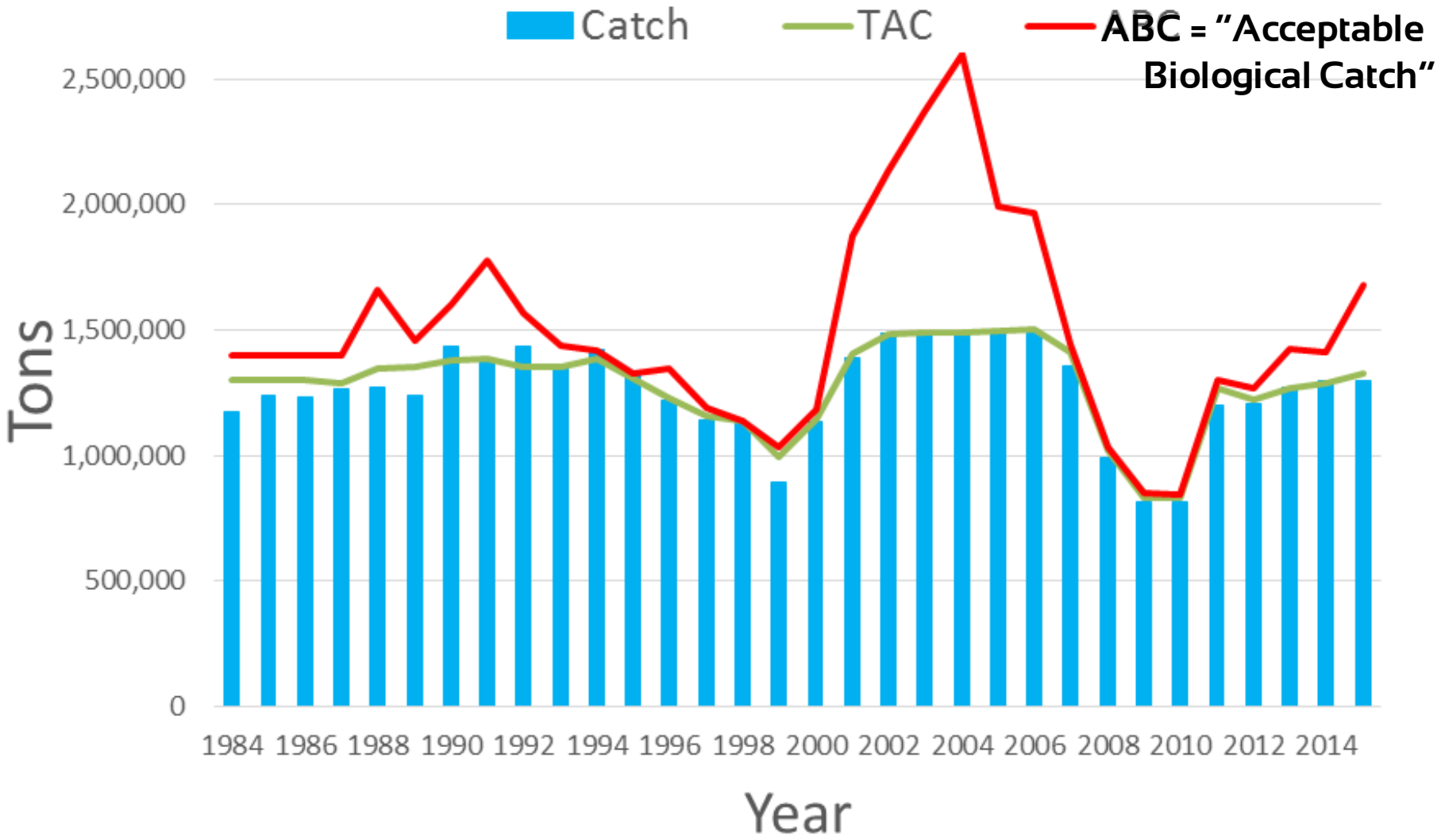


What fraction of the catch was immature?

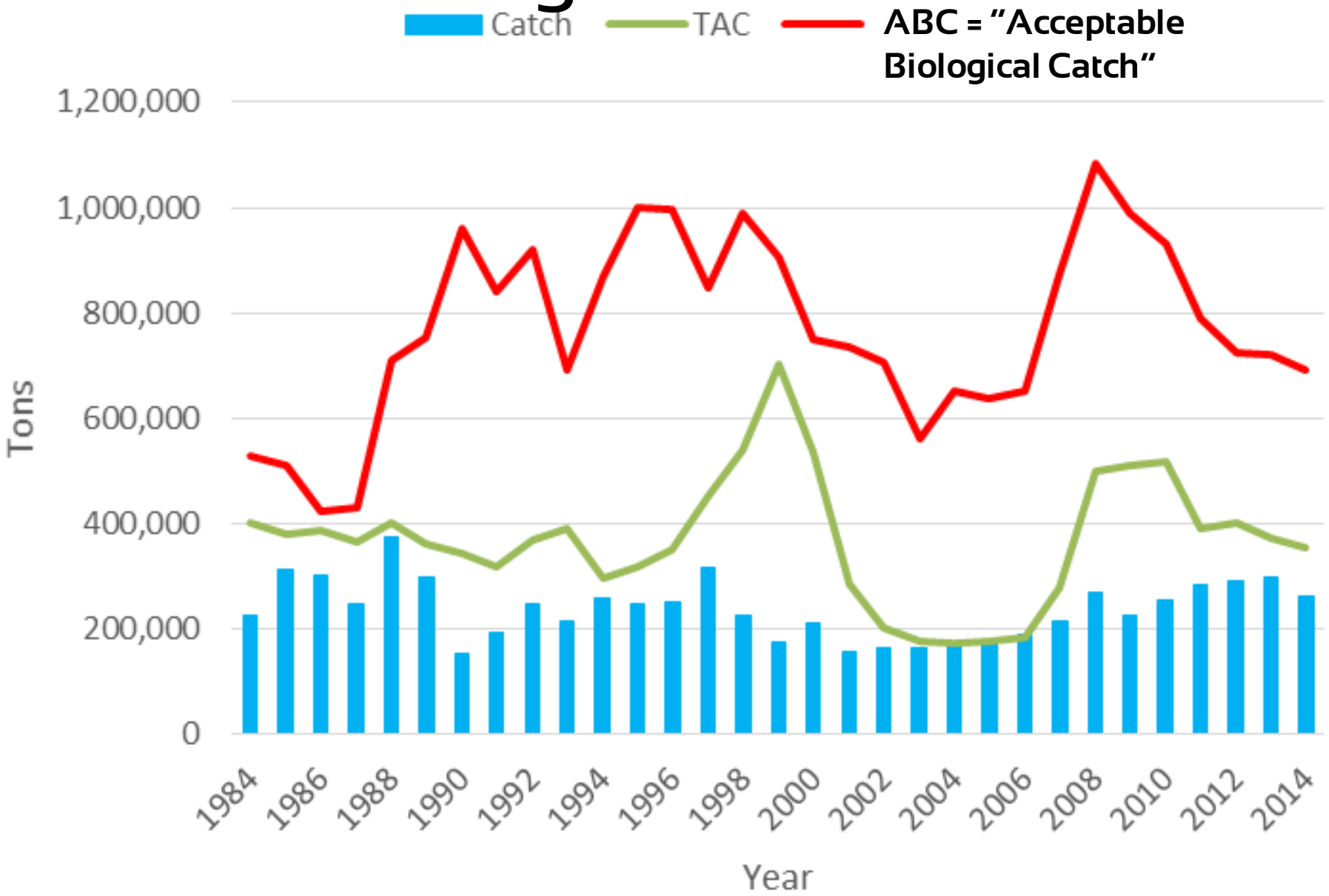


Catch relative to limits

EBS pollock

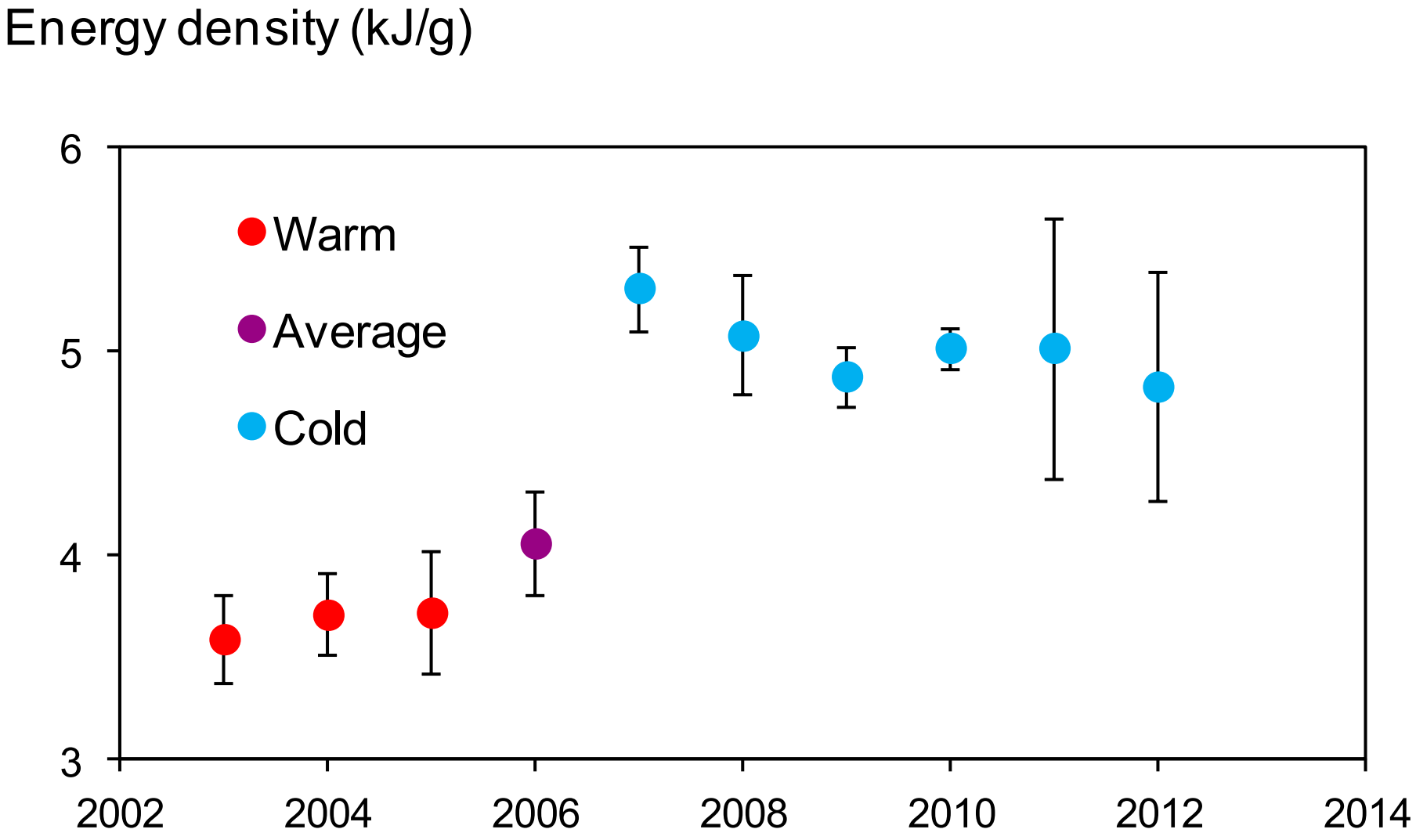


Bering sea flatfish



Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *recommended this* year for: 2016	2017
M (natural mortality rate, ages 3+)	0.3	0.3	0.3	0.3
Tier	1a	1a	1a	1a
Projected total (age 3+) biomass (t)	9,203,000 t	11,000,000 t	11,300,000 t	11,000,000 t
Projected female spawning biomass (t)	**2,850,000 t**	**2,950,000 t**	**3,540,000 t**	**3,500,000 t**
B_0	5,162,000 t	5,162,000 t	5,676,000 t	5,676,000 t
B_{MSY}	1,948,000 t	1,948,000 t	1,984,000 t	1,984,000 t
F_{OFL}	0.587	0.587	0.514	0.514
$maxF_{ABC}$	0.512	0.512	0.401	0.401
F_{ABC}	0.24	0.25	0.27	0.26
OFL (t)	3,330,000 t	3,490,000 t	3,910,000 t	3,540,000 t
maxABC (t)	2,900,000 t	3,040,000 t	3,050,000 t	2,760,000 t
ABC (t)	1,637,000 t	1,554,000 t	2,090,000 t	2,019,000 t
Status	2013	2014	As determined *this* year for: 2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Climate & age-0 pollock condition

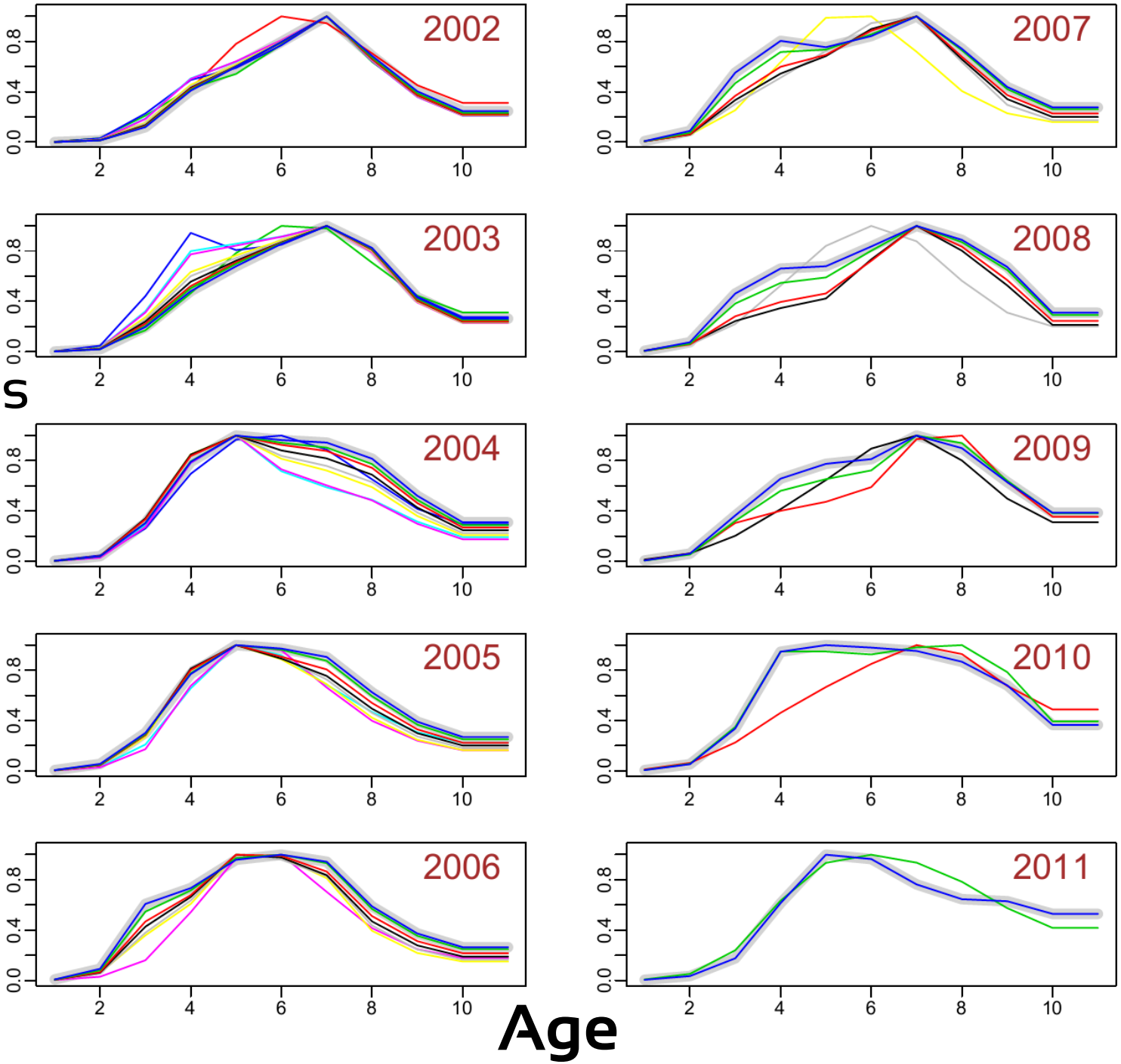


Courtesy: Heintz

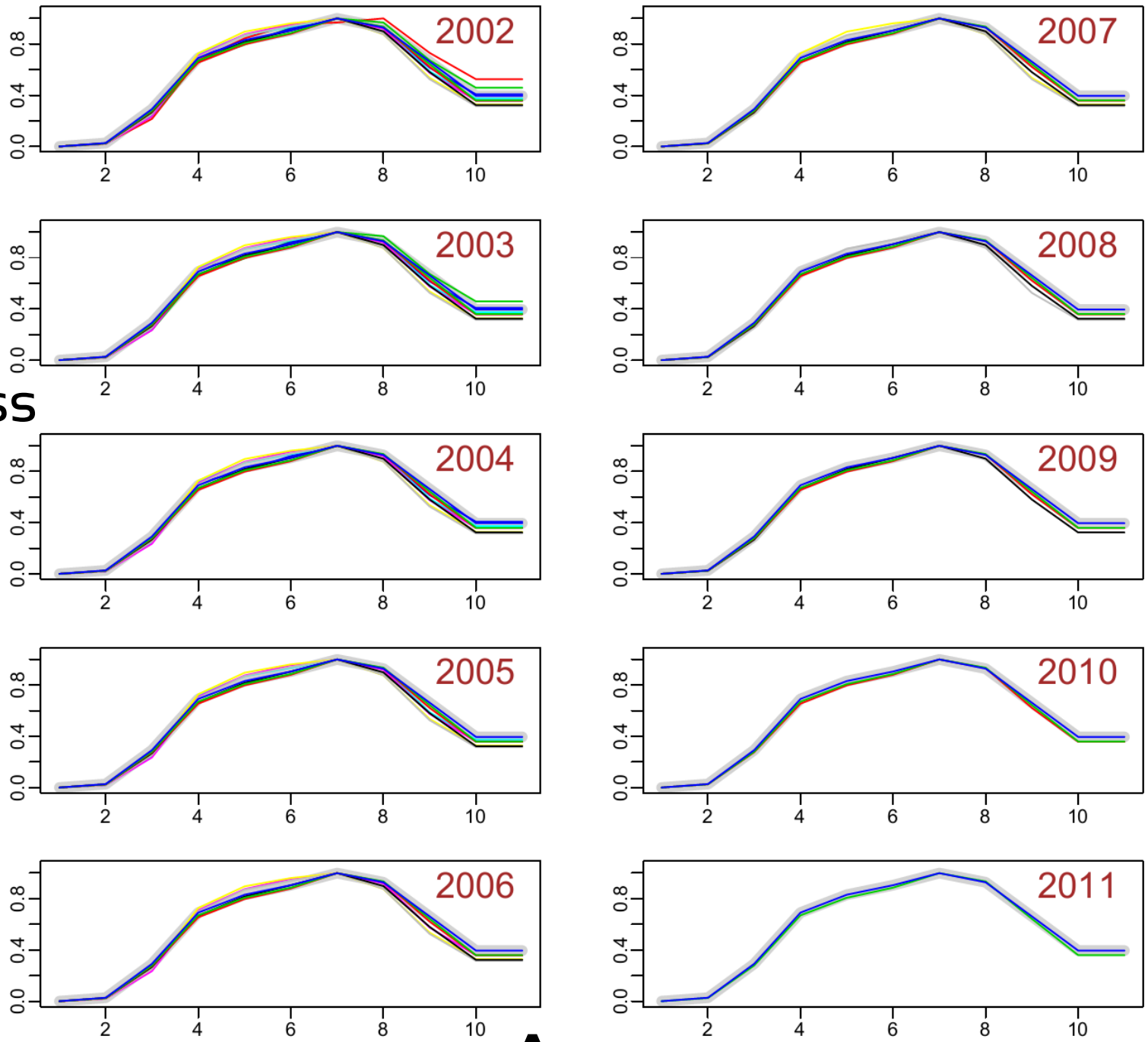
Diagnoses on retrospective patterns

- How much do selectivity estimates change given smoothness specification?
  - Qualitative for now
  - Akin to cross-validation

Low smoothness constraint



Estimated smoothness constraint



Age

Selectivity estimation for ABC

Requires some sort of projection

- Typically recent mean value

Could this be an issue when strong cohorts are targeted?

Alternative yet-to-be-fully-tested method:

- Including cohort effects on selectivity