



Gulf of Alaska Pacific cod

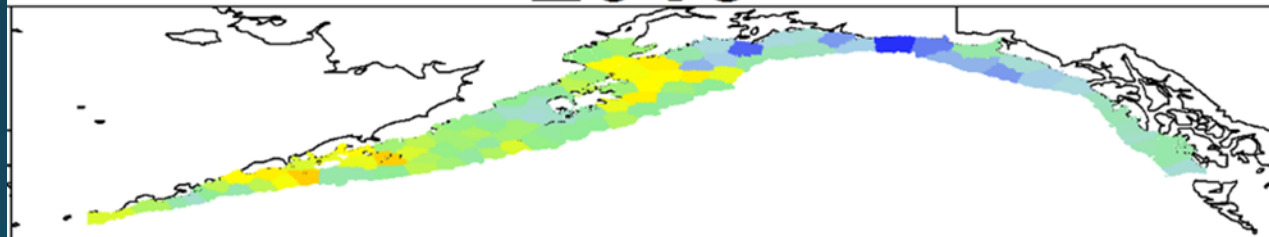
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Ben Fissel, Kirstin Holsman,
Kalei Shotwell, Wayne Palsson,
Qiong Yang, and Stephani Zador
NPFMC SSC

November 12, 2017

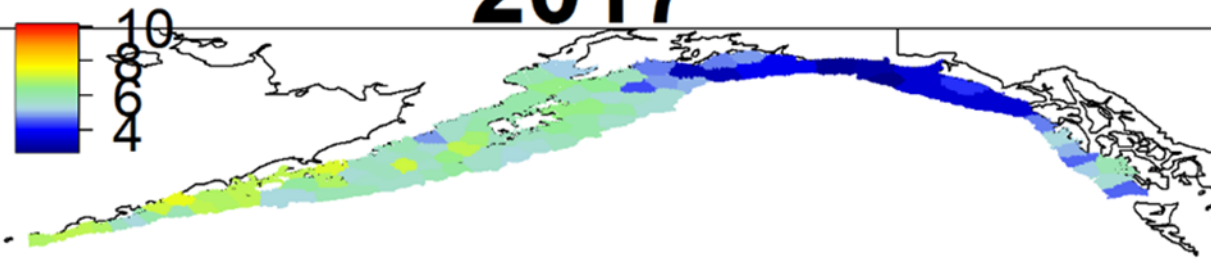


“Would you please elaborate on ‘then something bad happened?’”

2015



2017



GOA Pacific cod Status

- Tier 3b ($B_{2018} = B_{21.5\%}$)
- 77% decrease in ABC from last year's projection
- Apportionment based on random effects model

Authors' recommended Model 17.09.35

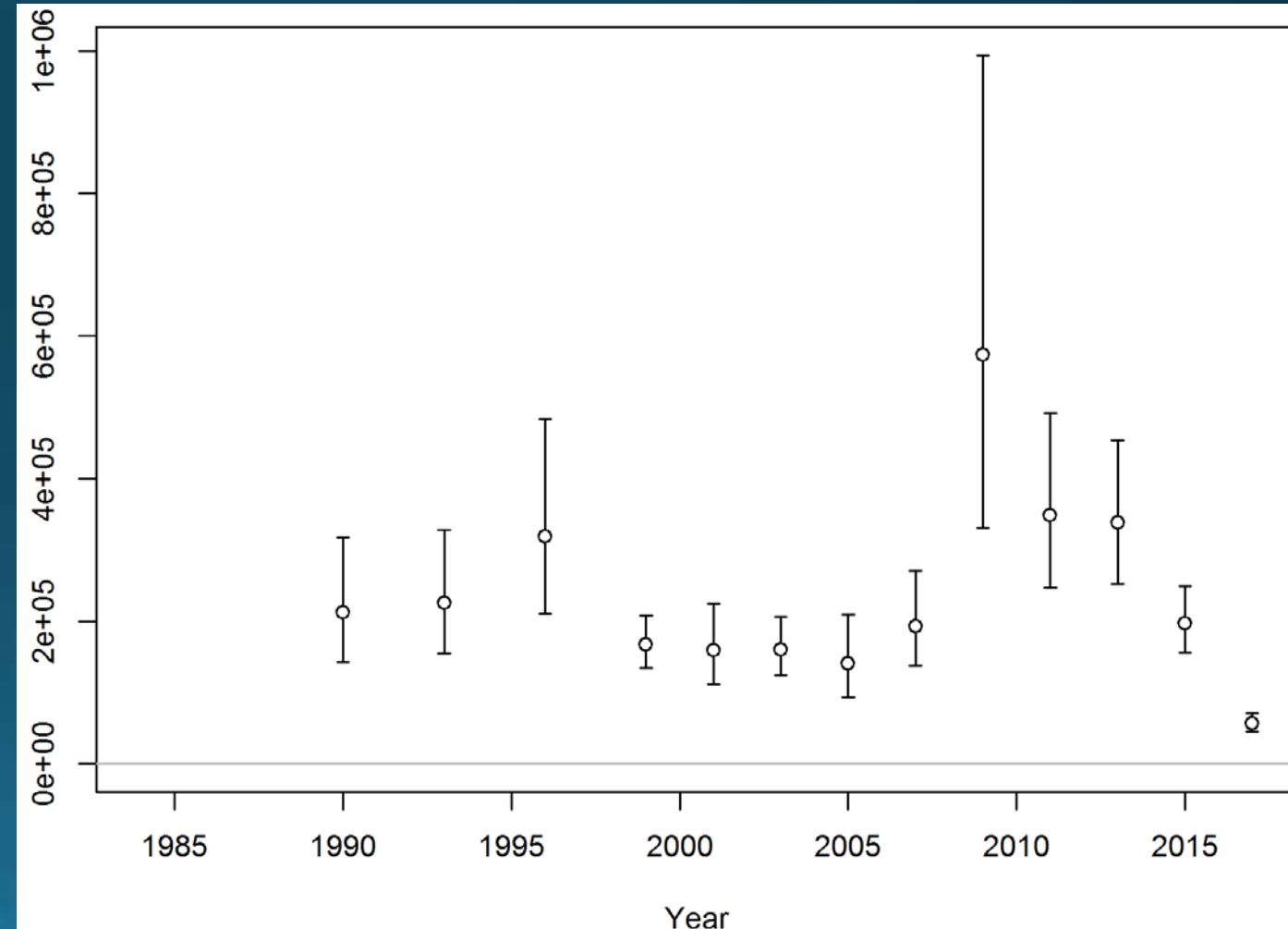
Quantity	As estimated or specified last year for:		As estimated or specified this year for:	
	2017	2018	2018	2019
M (natural mortality rate)	0.47	0.47	0.49	0.49
Tier	3a	3a	3b	3b
Projected total (age o+) biomass (t)	426,384	428,885	170,565	198,942
Female spawning biomass (t)				
Projected	91,198	98,479	36,209	34,424
$B_{100\%}$	196,776	196,776	168,583	168,583
$B_{40\%}$	78,711	78,711	67,433	67,433
$B_{35\%}$	68,872	68,872	59,004	59,004
F_{OFL}	0.652	0.652	0.42	0.40
$maxF_{ABC}$	0.530	0.530	0.34	0.32
F_{ABC}	0.530	0.530	0.31	0.31
OFL (t)	105,378	94,188	23,565	21,412
maxABC (t)	88,342	79,272	19,401	17,634
ABC (t)	88,342	79,272	18,000	17,000
	As determined this year for:			
Status	2015	2016	2016	2017
Overfishing	no	n/a	No	n/a
Overfished	n/a	no	n/a	No
Approaching overfished	n/a	no	n/a	No

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	44.9	45.1	10.0	100.00
2018 ABC	8,082	8118	1,800	18,000
2019 ABC	7,633	7,667	1,700	17,000

GOA Pacific cod 2017 Bottom trawl survey

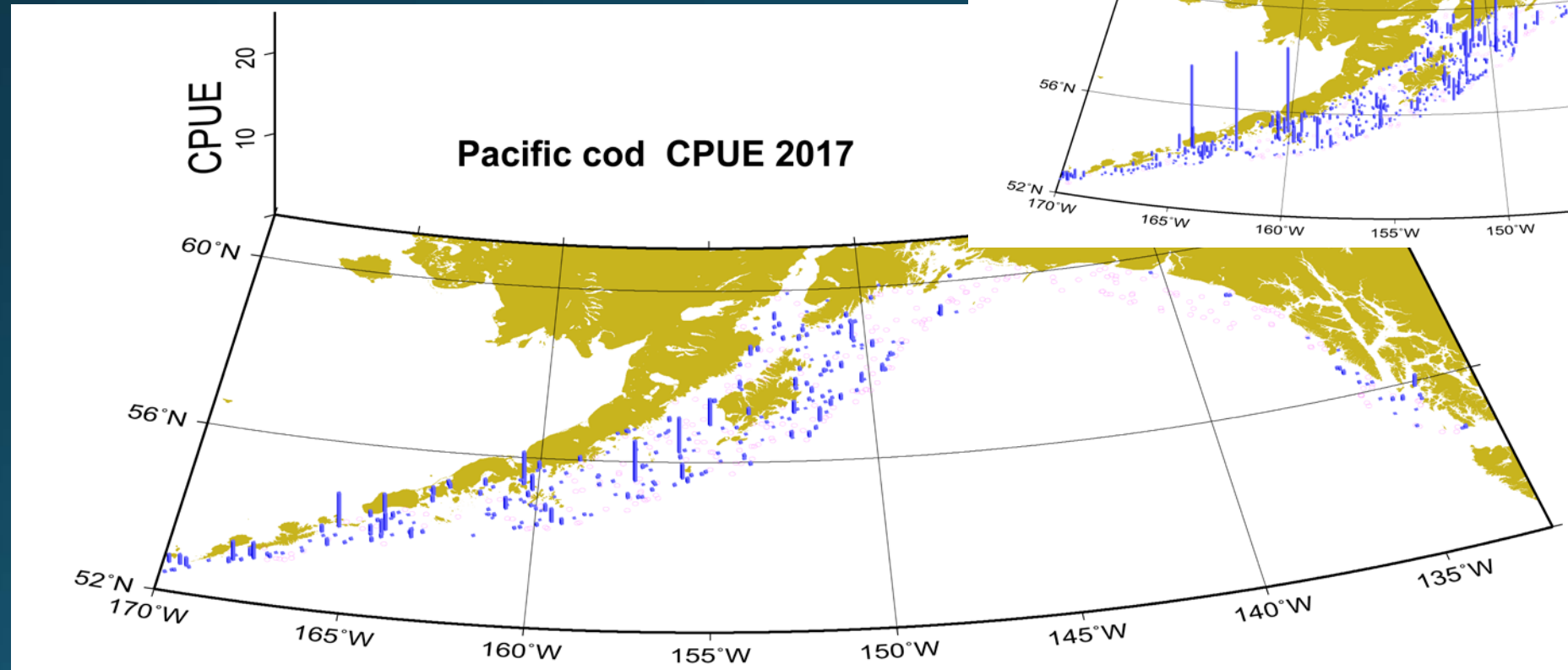
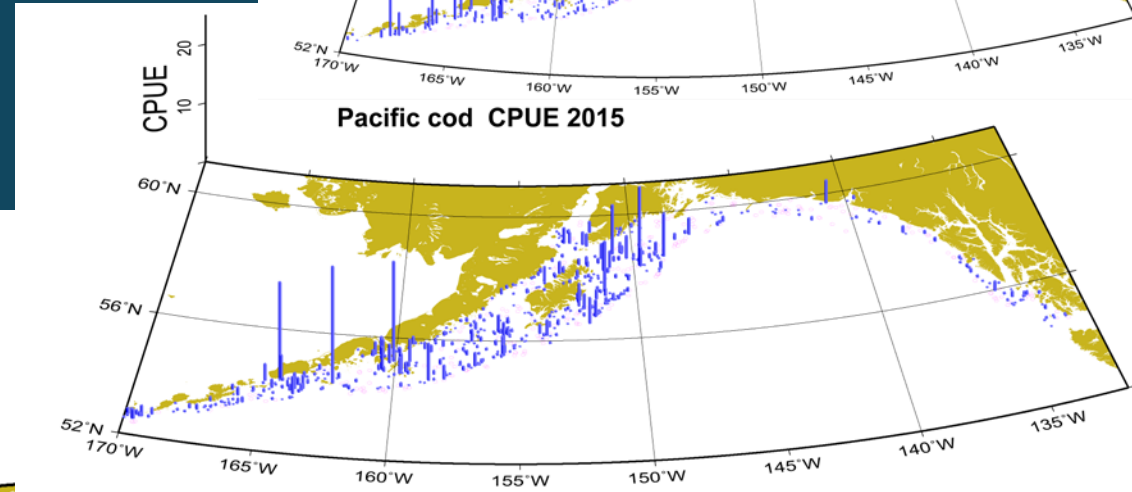
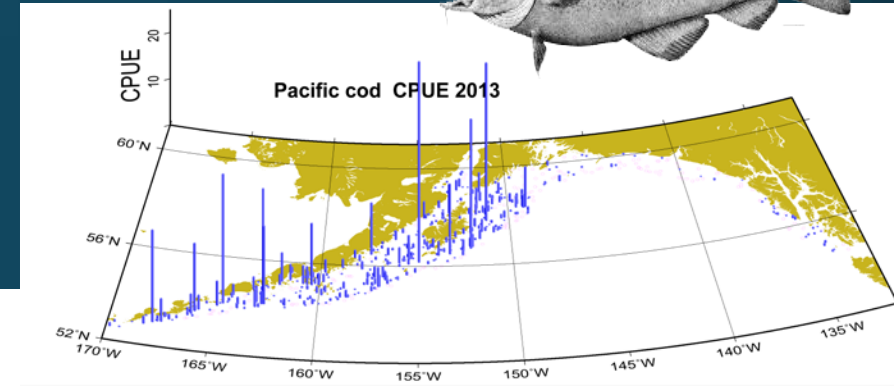


- Lowest estimate ever
 1.96×10^8 fish and 107,324 t
- Precise estimate (0.117 CV)
- 71% decline in abundance
since 2015 (83% since 2013)
- 58% decline in biomass
since 2015 (78% since 2013)



GOA Pacific cod Bottom trawl survey

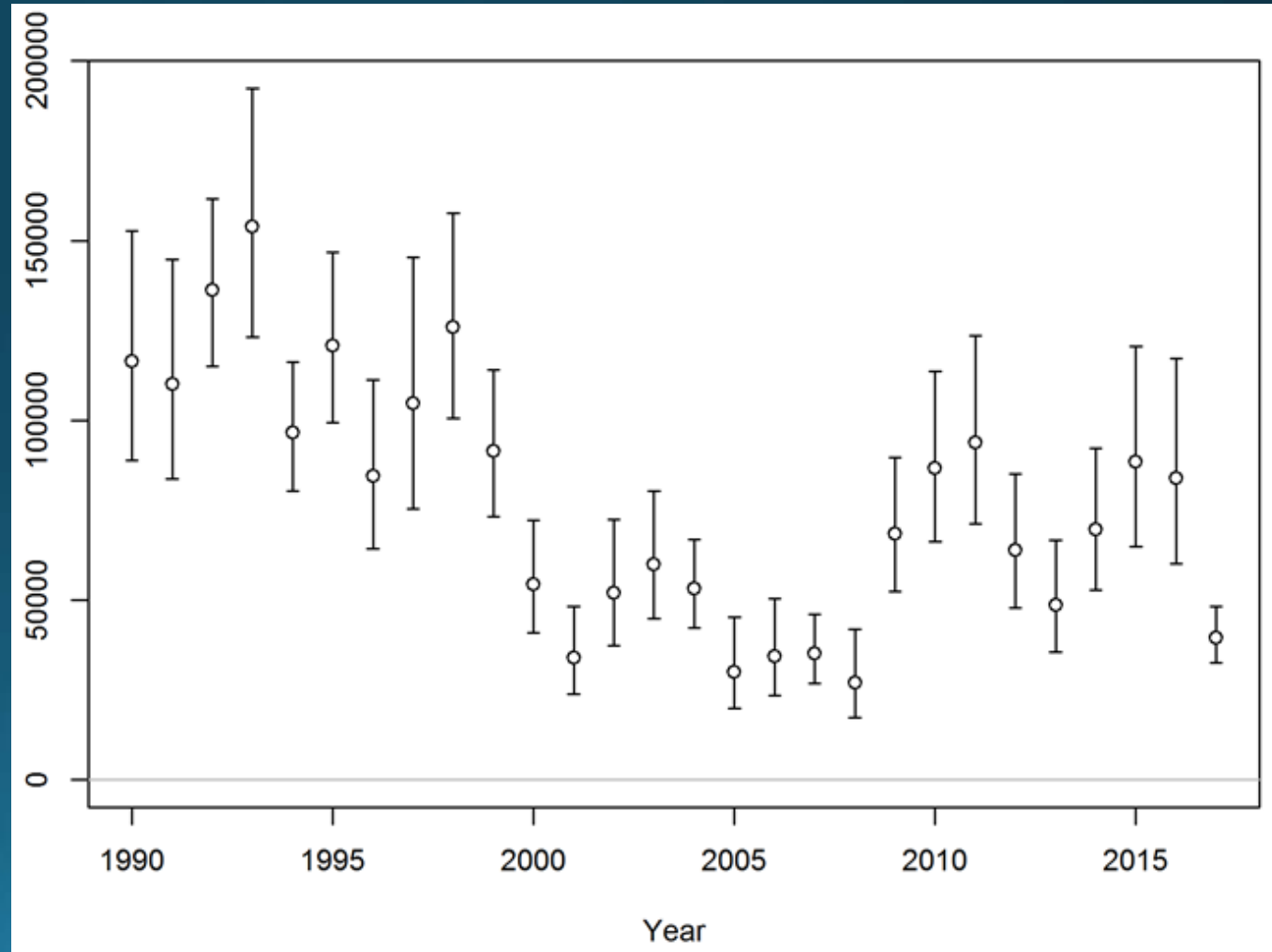
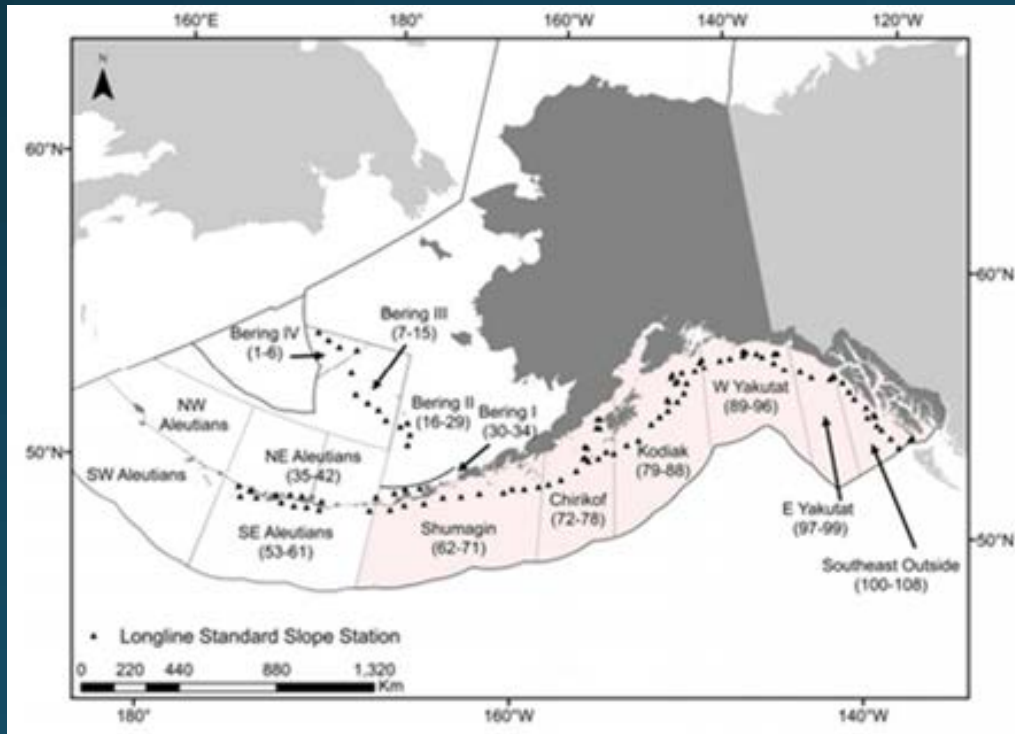
- Low density through surveyed area
- Some medium-low density along Alaska Peninsula and south of Unimak Island



GOA Pacific cod AFSC longline survey



- Low index value (39,523 RPN)
- 53% decline from 2016



GOA Pacific cod

Other surveys

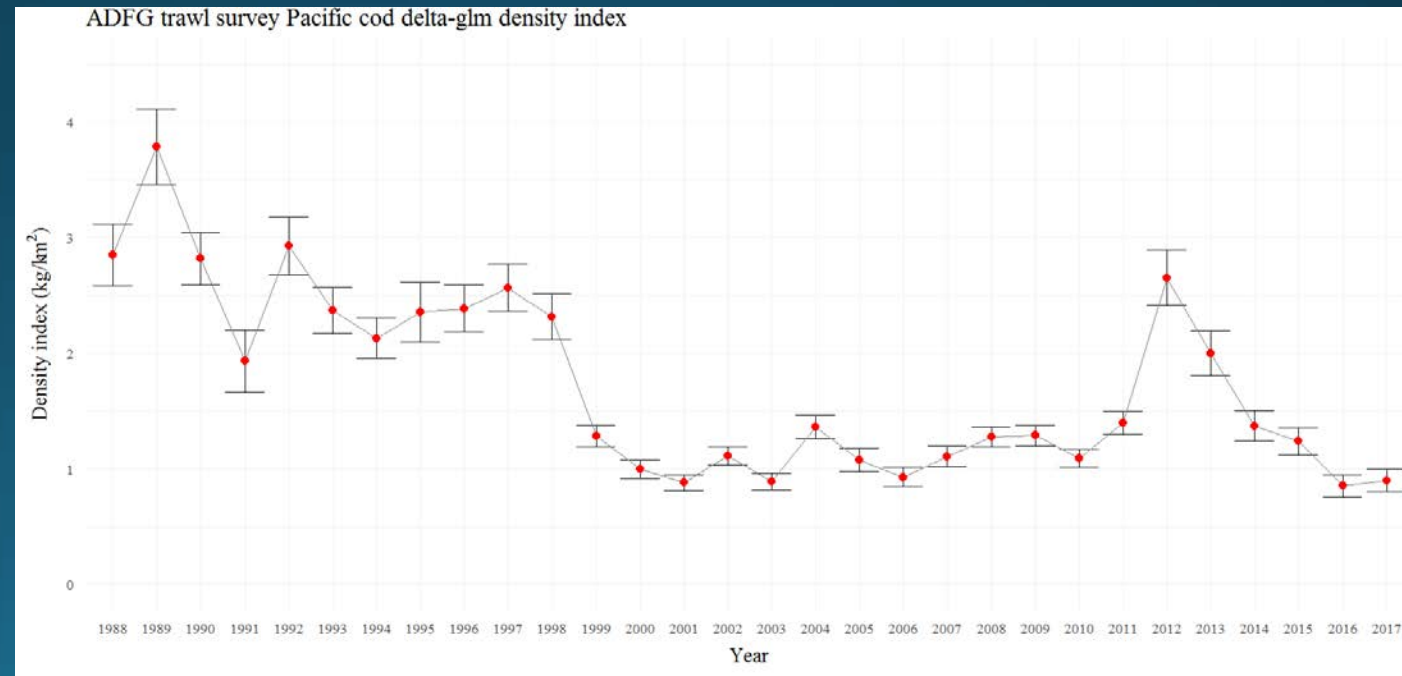
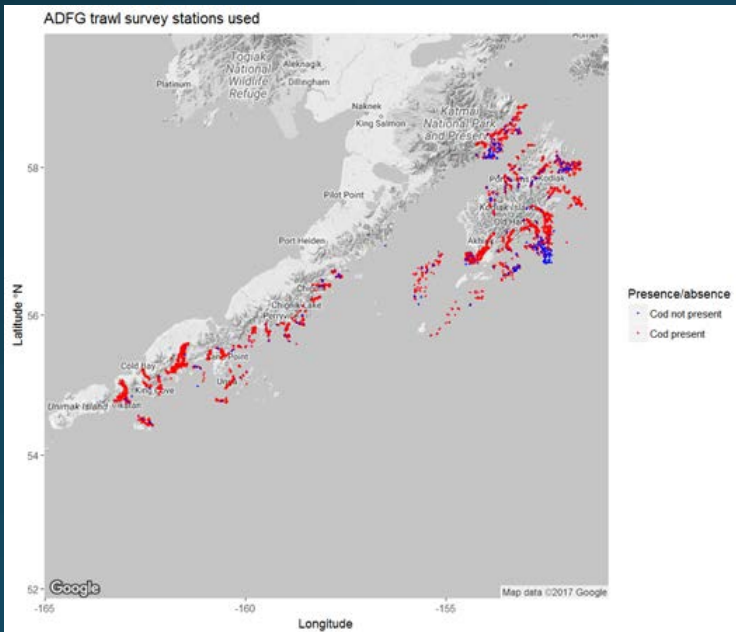
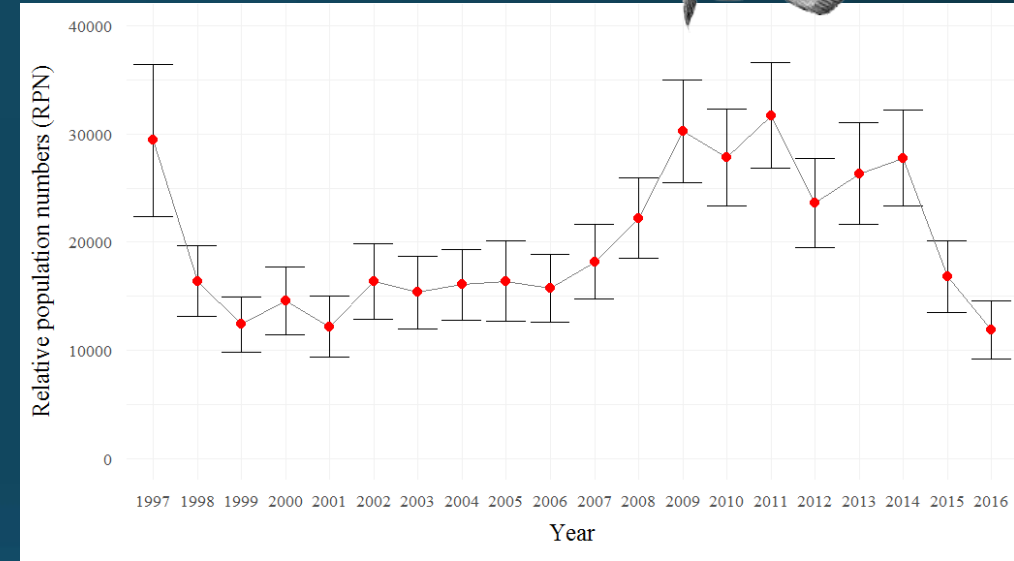


IPHC longline survey 1997-2016

- 2016 Lowest

ADFG trawl survey 1988-2017

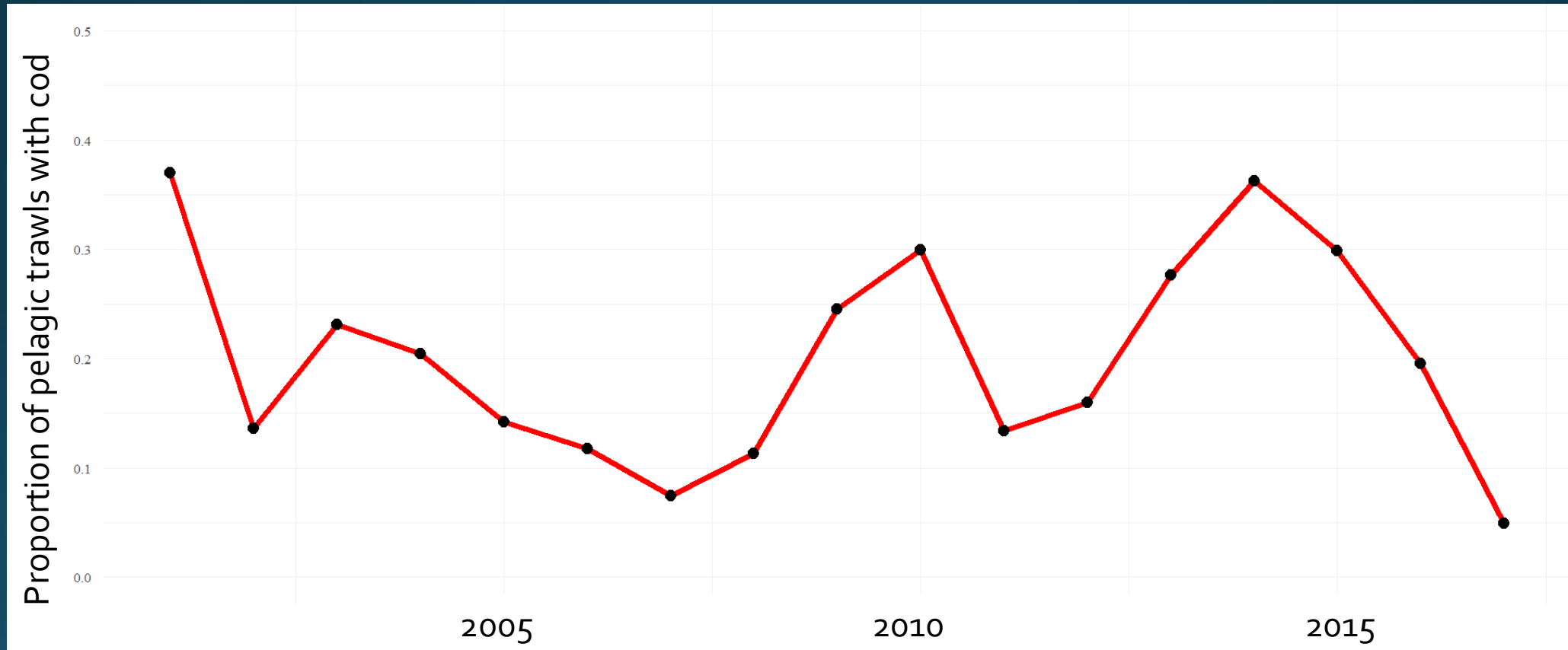
- Delta-GLM fit
- 2016 lowest
- 2017 slight increase from 2016 in Western GOA



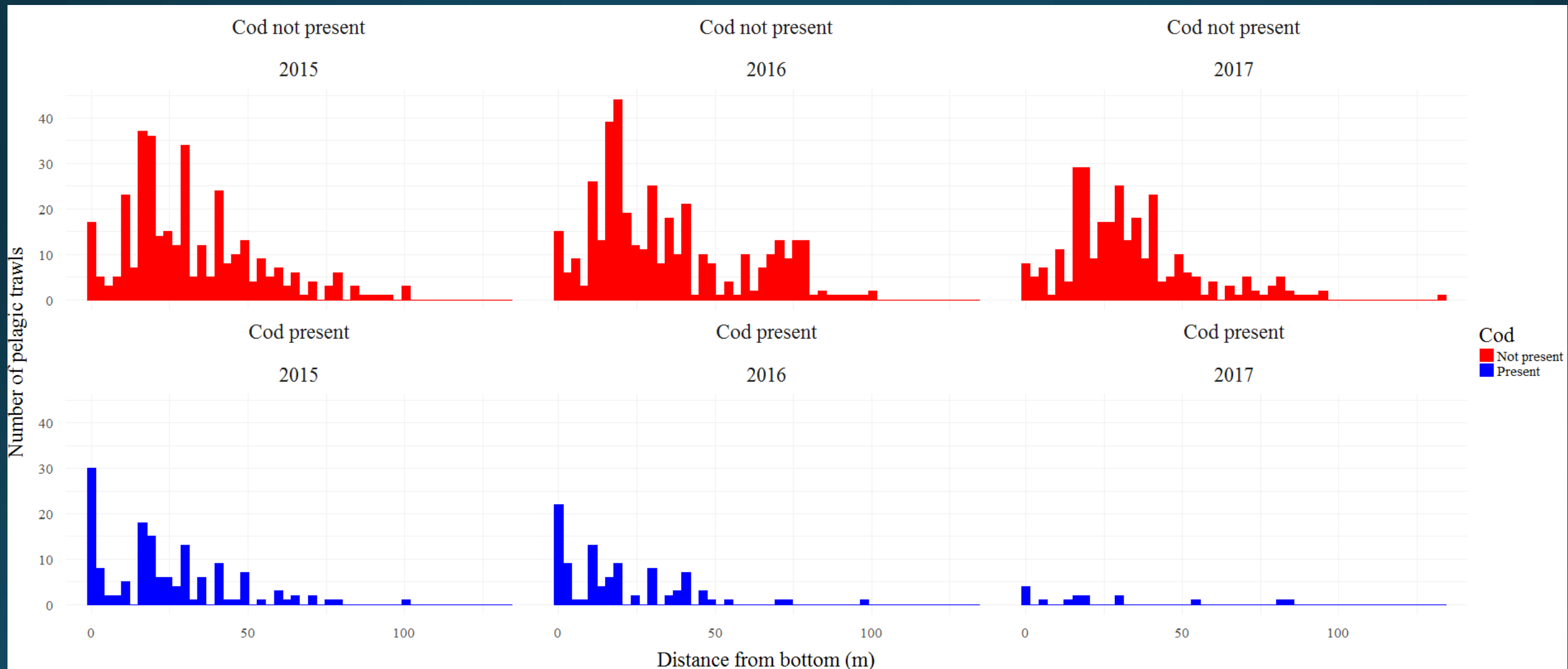
GOA Pacific cod Bycatch in pollock fishery



- Proportion of pelagic pollock trawl hauls with pacific cod (Jan-Aug)



GOA Pacific cod- Bycatch in pollock fishery

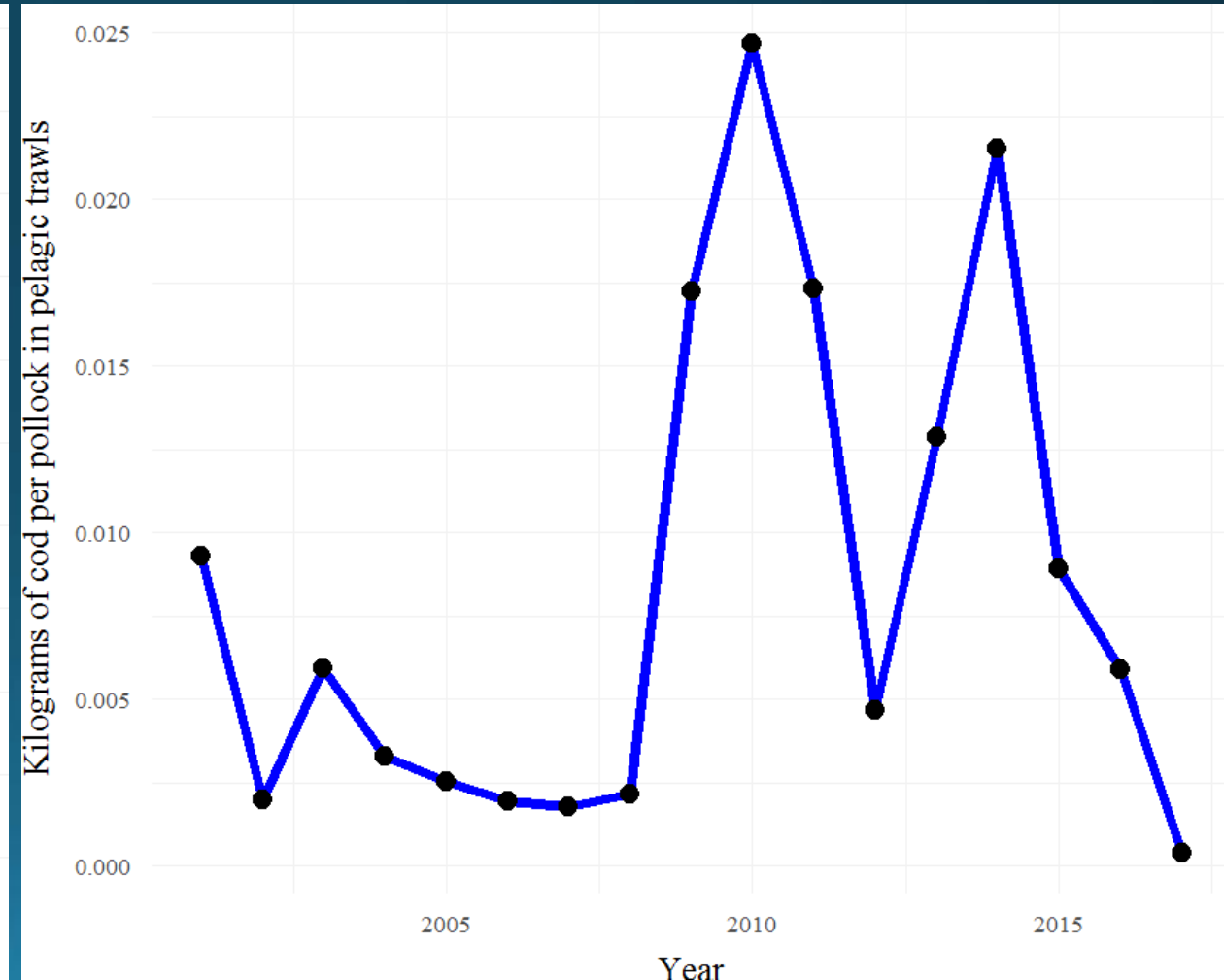
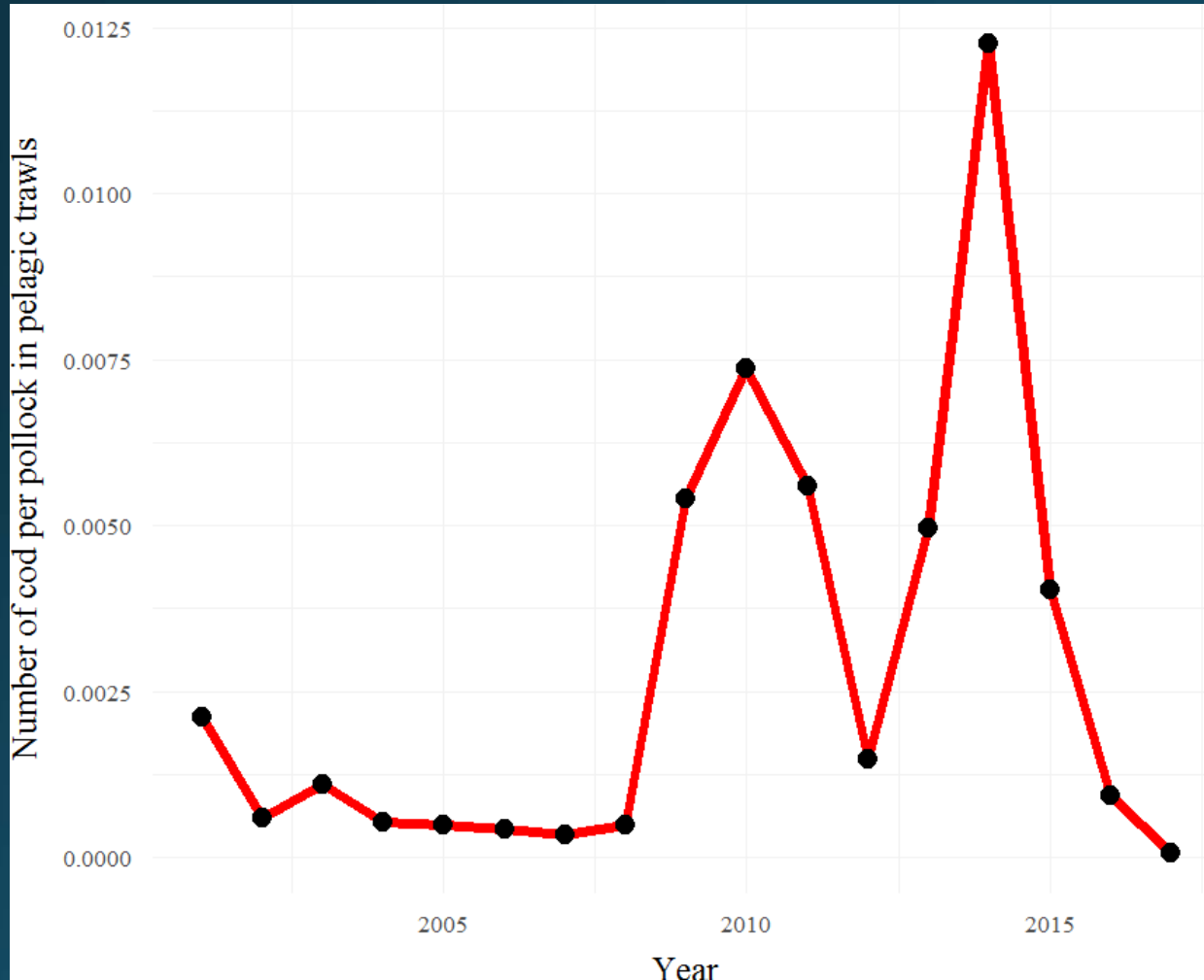


GOA Pacific cod Bycatch in pollock fishery



Number of cod per pollock

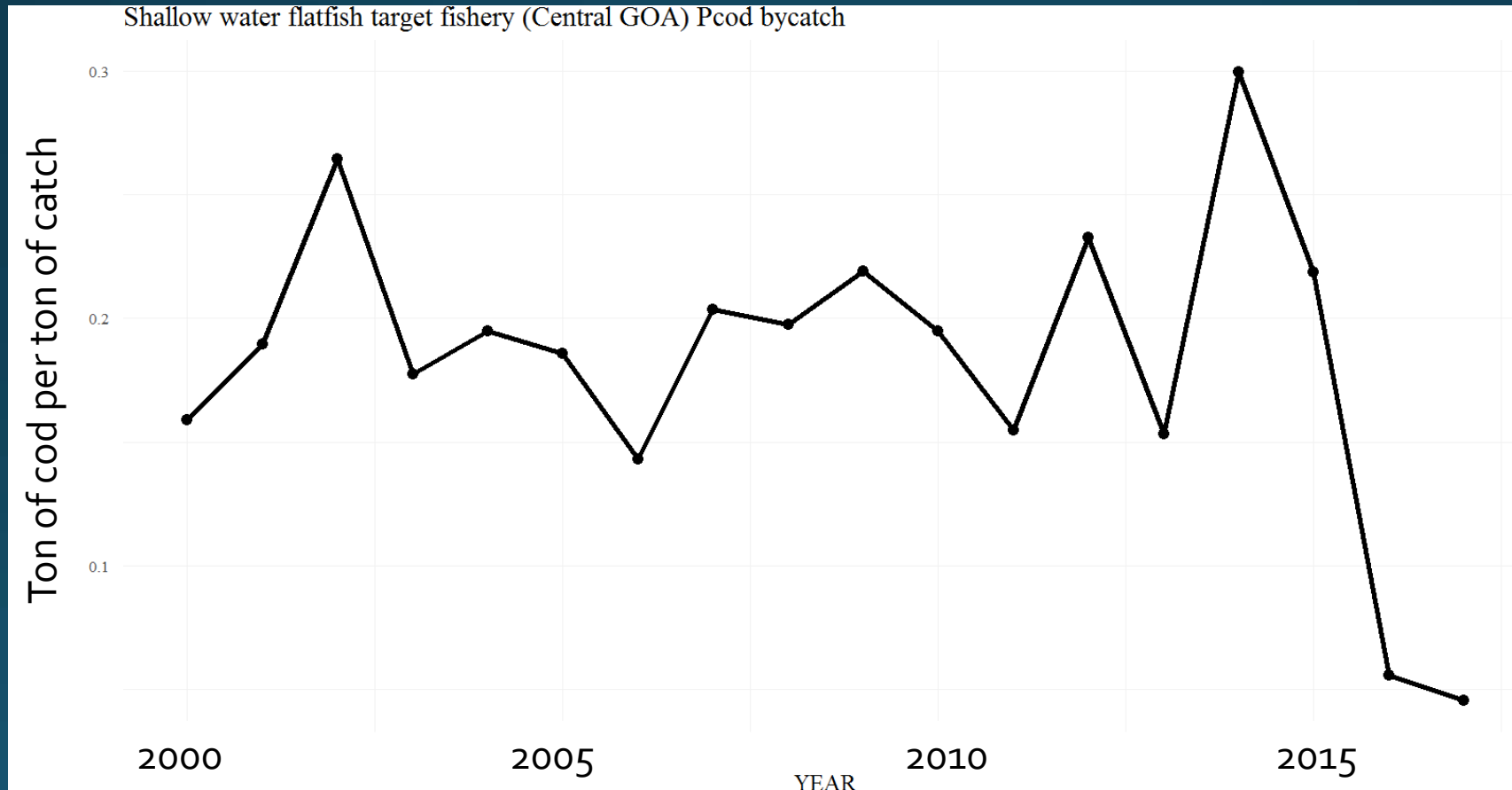
KG of cod per KG of pollock



GOA Pacific cod Bycatch in shallow water flatfish fishery



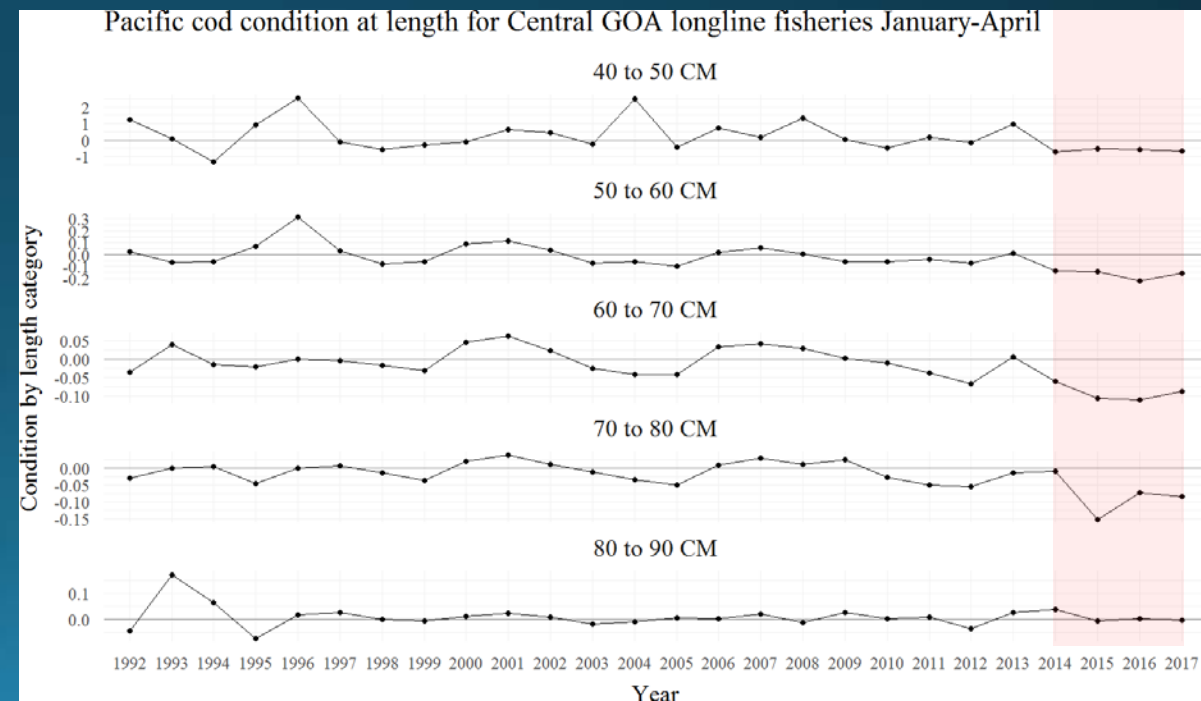
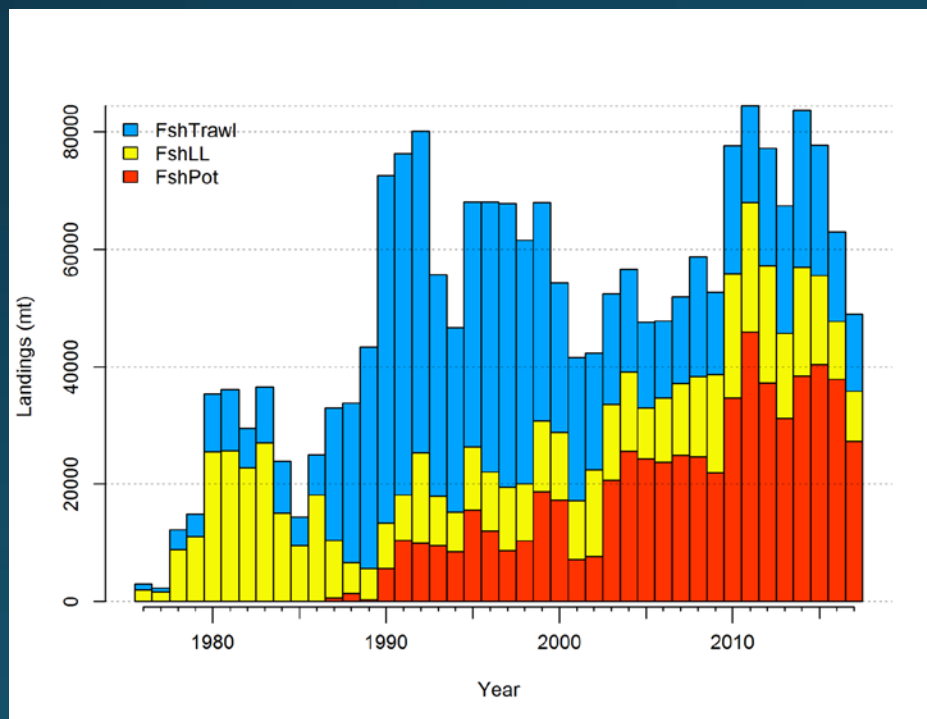
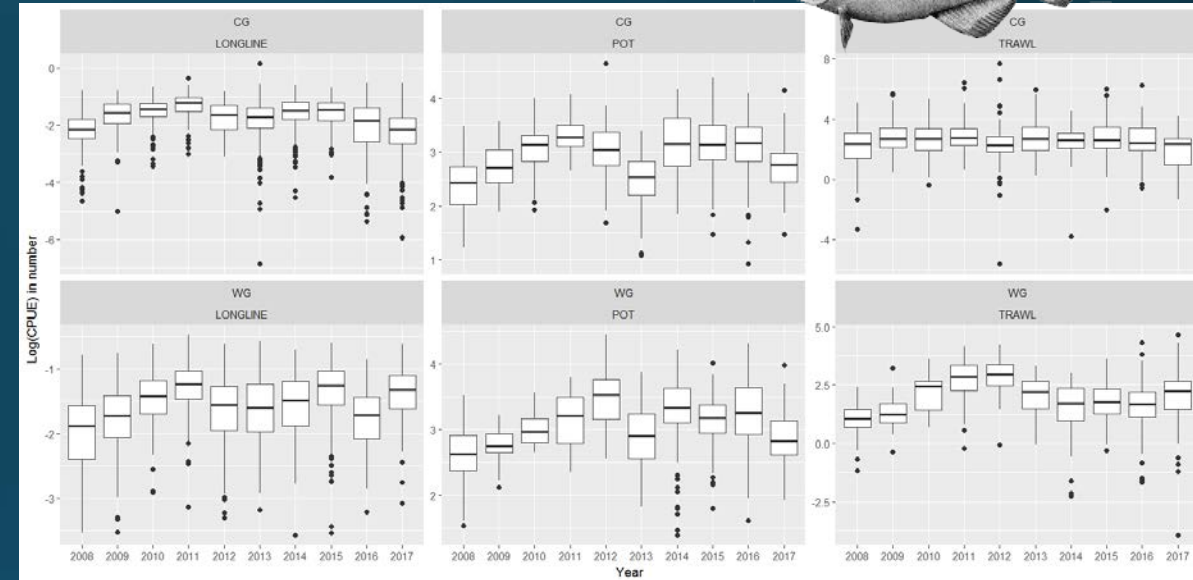
- January-August for all years – only Central GOA



GOA Pacific cod Fishery data



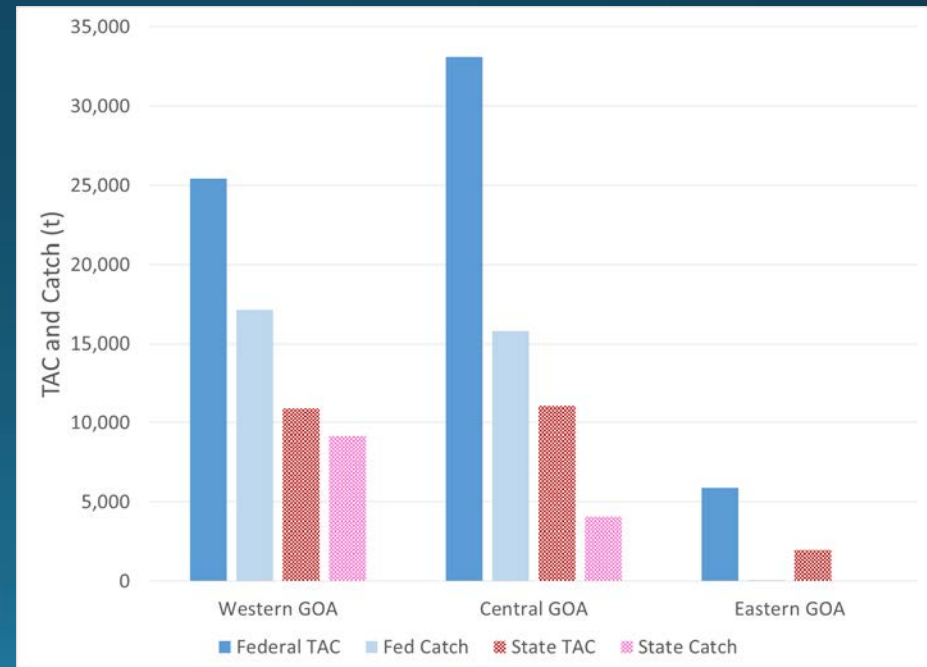
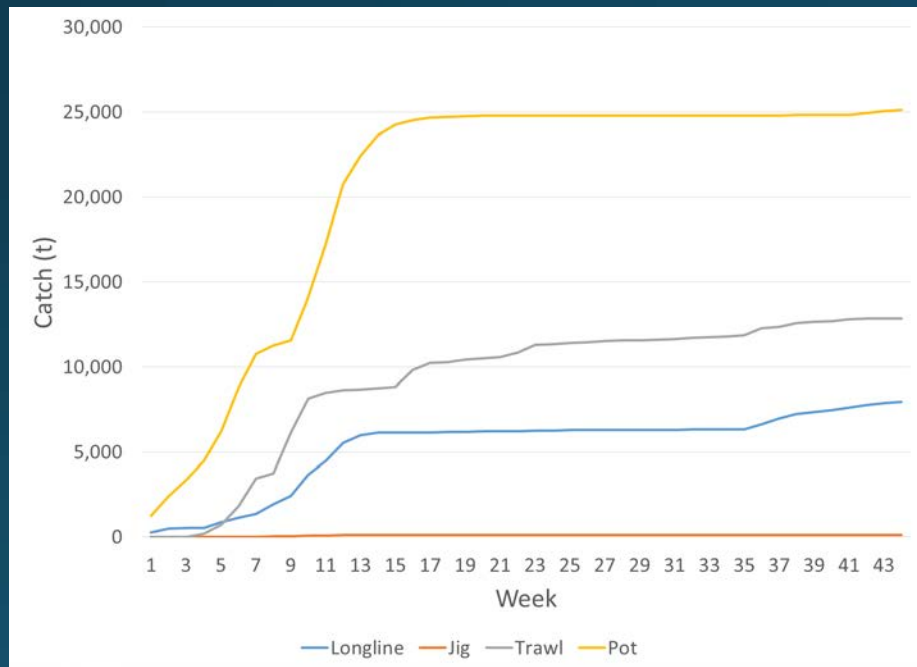
- Catch at < 60% of ABC
- Low CPUE in Central GOA all fisheries
- Low CPUE in pot fishery in Western GOA, high CPUE for other sectors
- Poor condition for 2014-2017 in longline and pot fisheries for fish < 80cm



GOA Pacific cod 2017 Fishery data

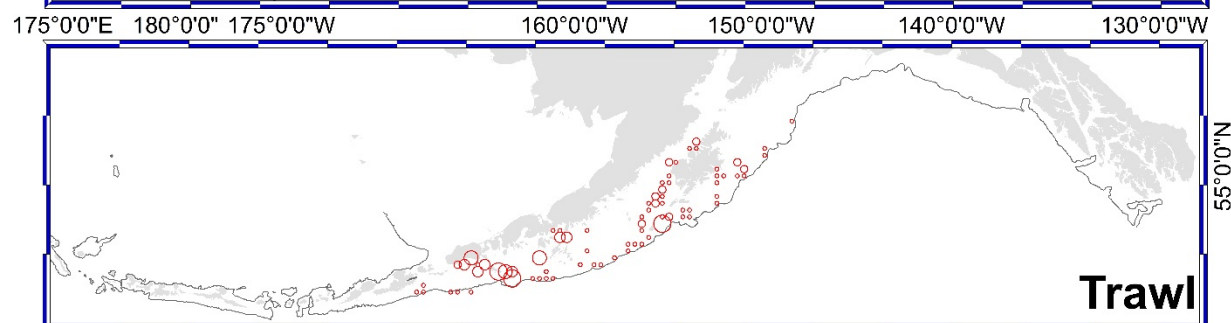
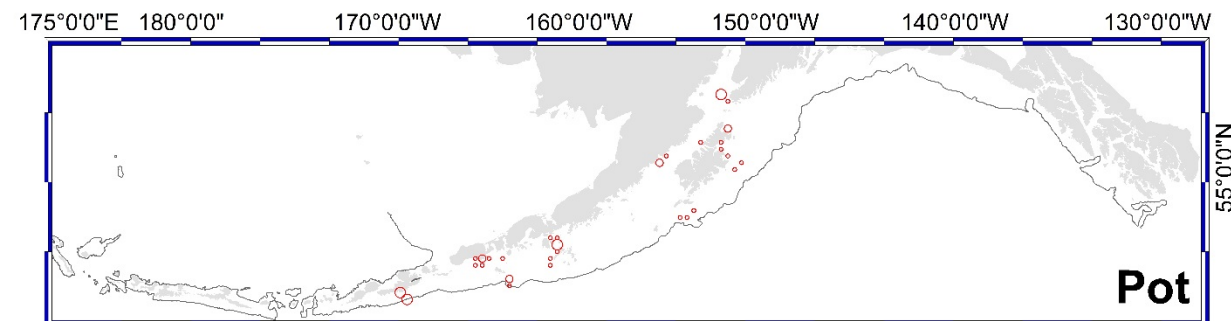
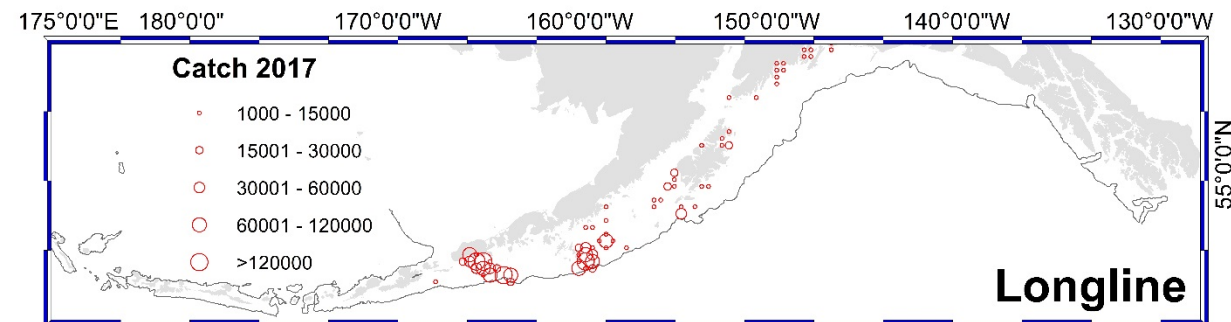
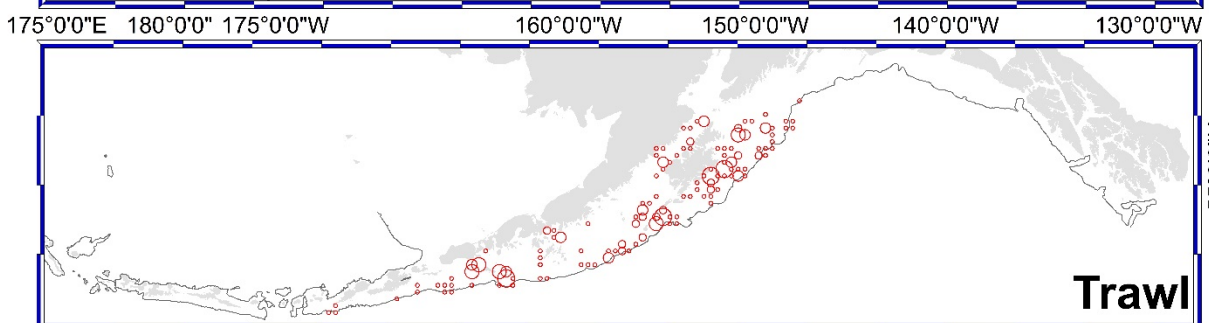
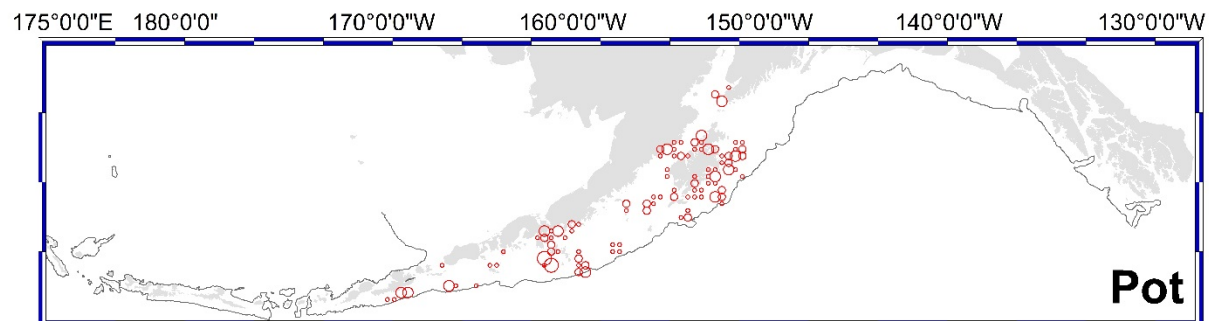
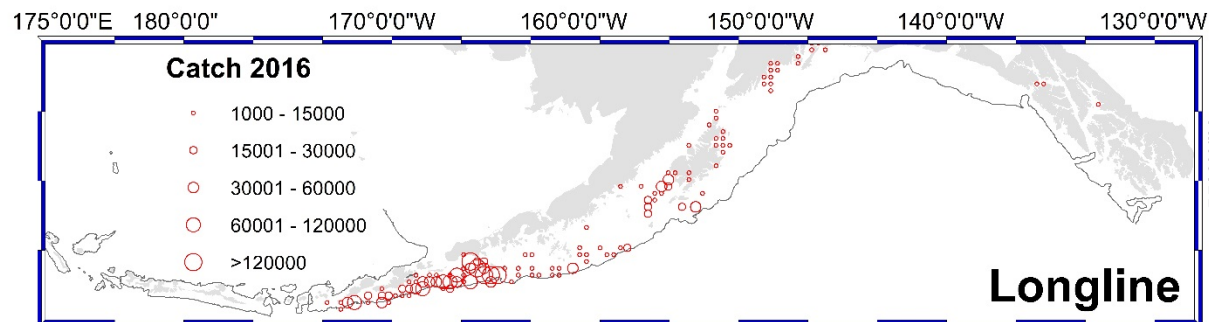


- 2017 combined state and federal fishery currently at 52% of ABC
 - Western GOA 72% of ABC (67.6% Federal and 84.1% State)
 - Central GOA 45% of ABC (47.6% Federal and 36.8% State)
 - Eastern GOA at < 1% of ABC (< 1% Federal and State)



*As of 11/4/2017

GOA Pacific cod Fishery data – observed distribution



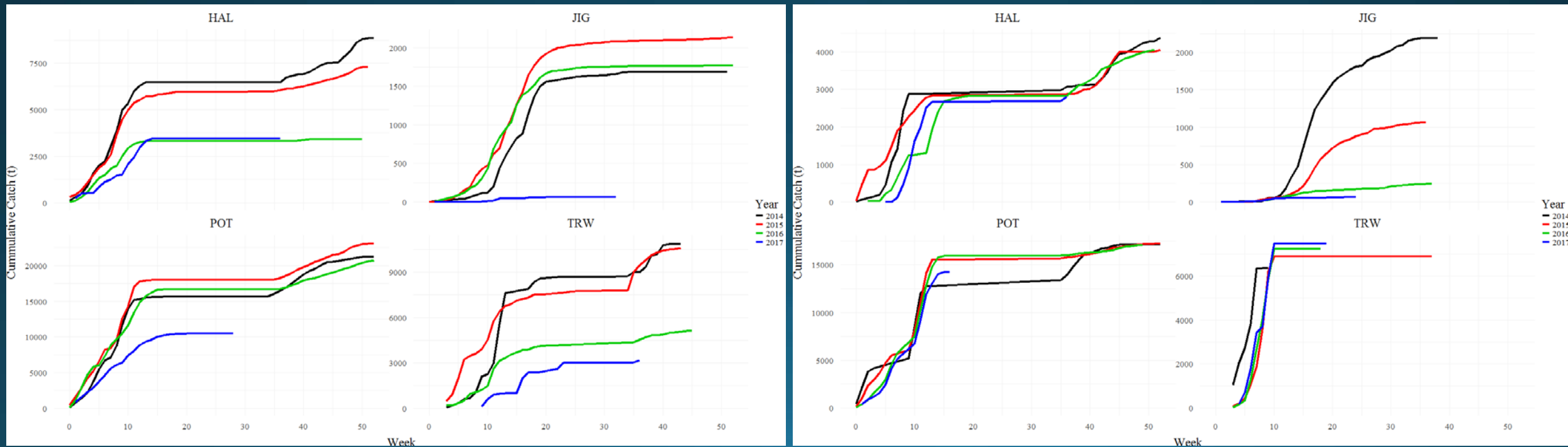
GOA Pacific cod Fishery data



- Slow start in the Central GOA, Western GOA similar to 2016

Central GOA

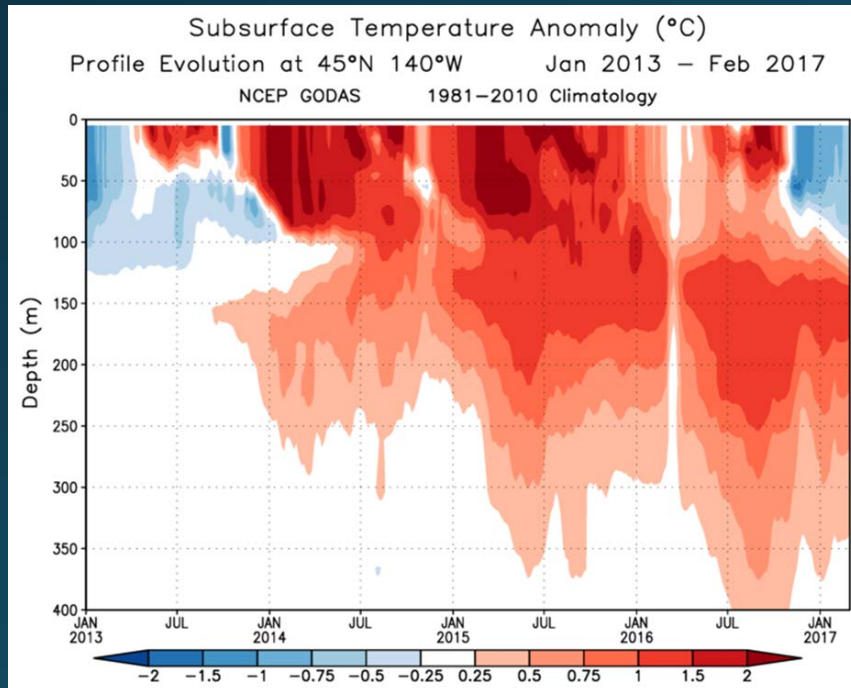
Western GOA



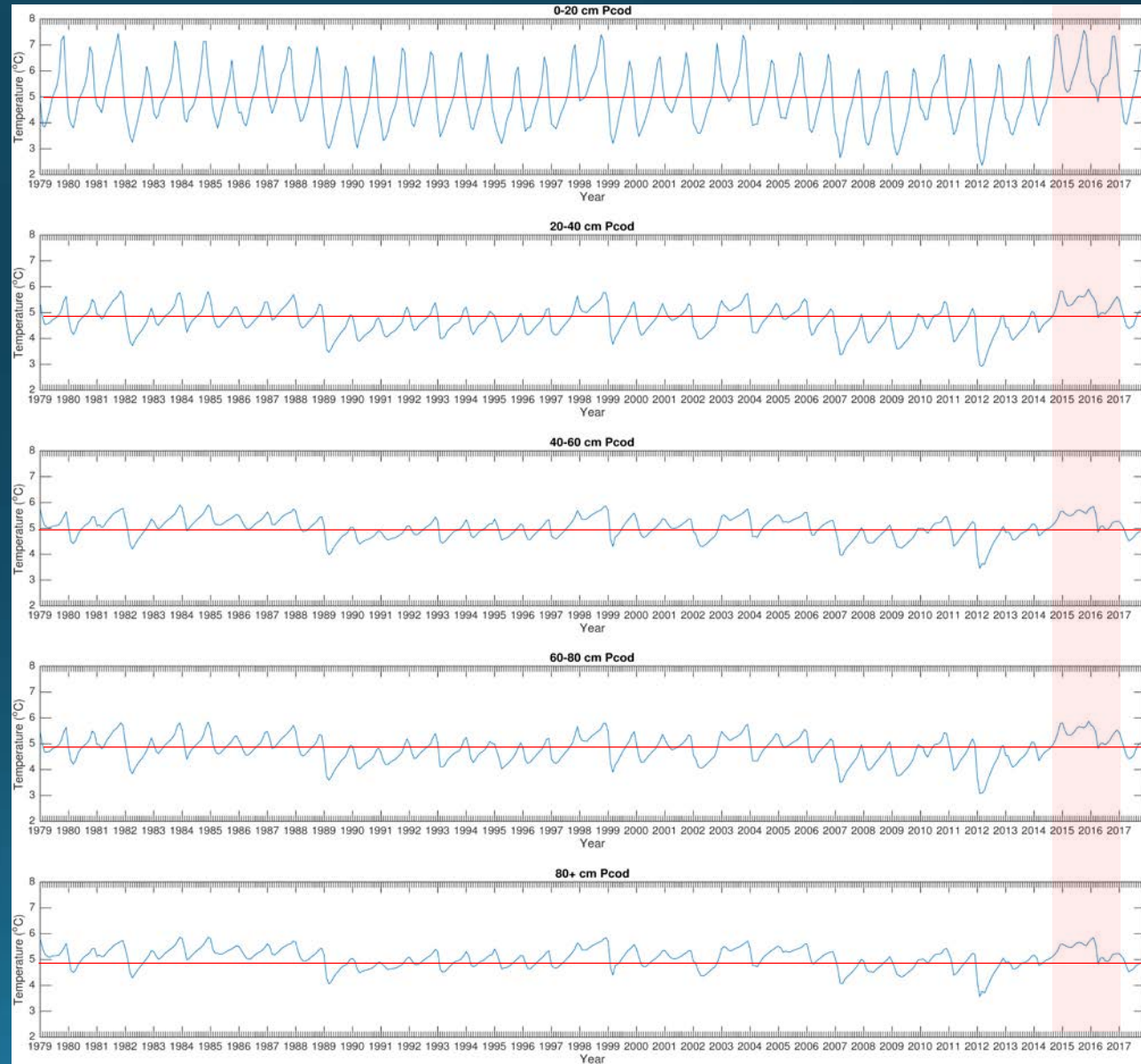
Anomalously warm waters 2014-2016



- Anomalously warm waters 2014-2016
- Deep and continued throughout the year



CFSR analysis by Qiong Yang



Anomalously warm waters 2014-2016



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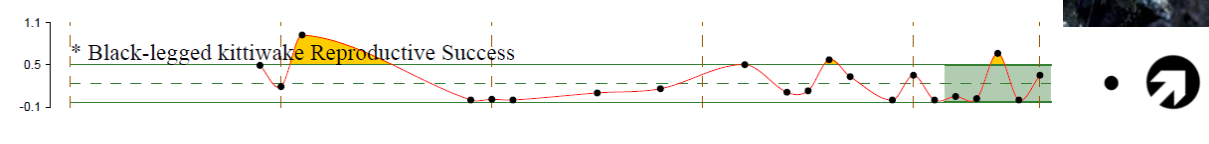
Science

Scientists think Gulf of Alaska seabird die-off is biggest ever recorded

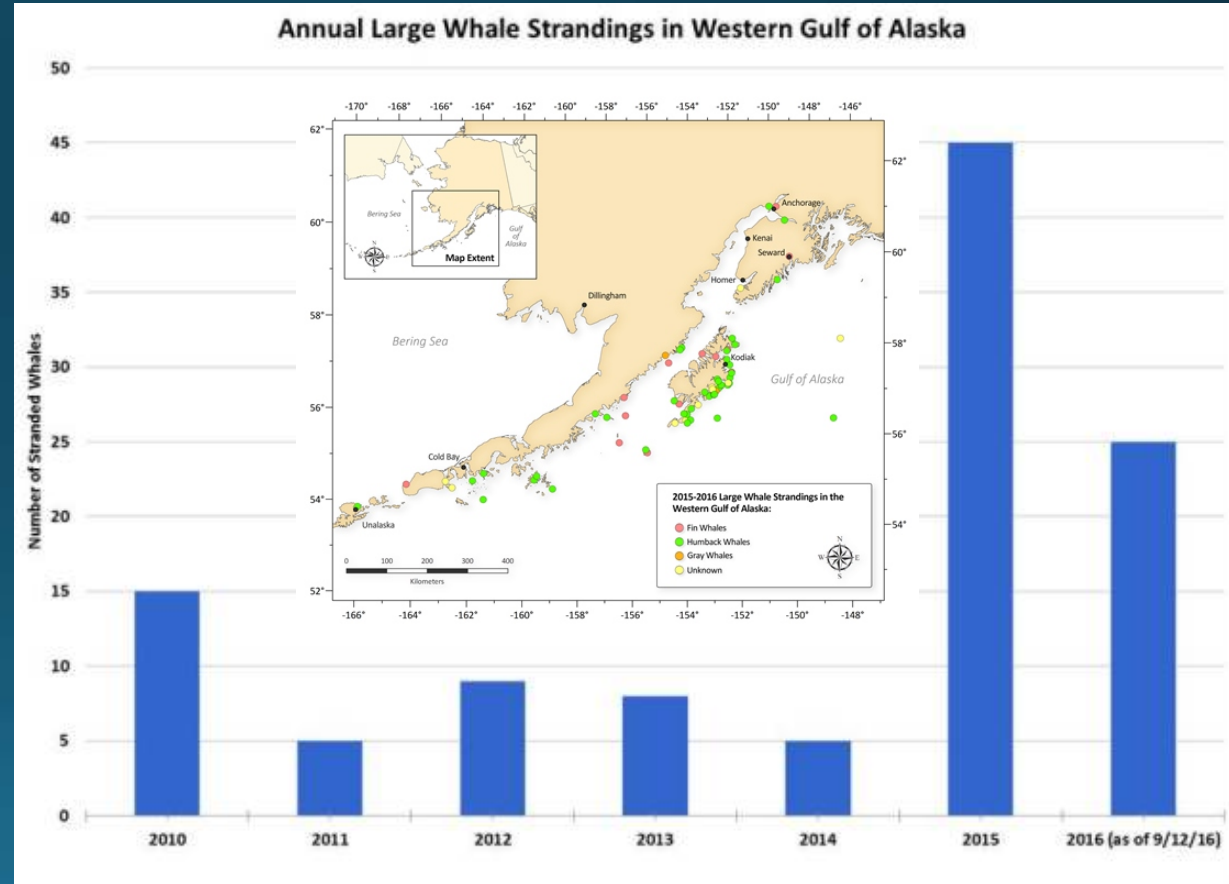
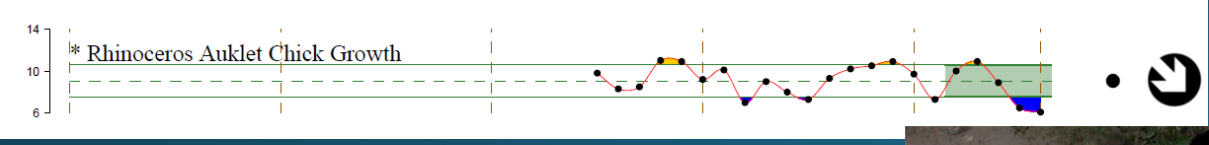
Author: **Yereth Rosen** | Updated: September 30, 2016 | Published January 29, 2016



West



East

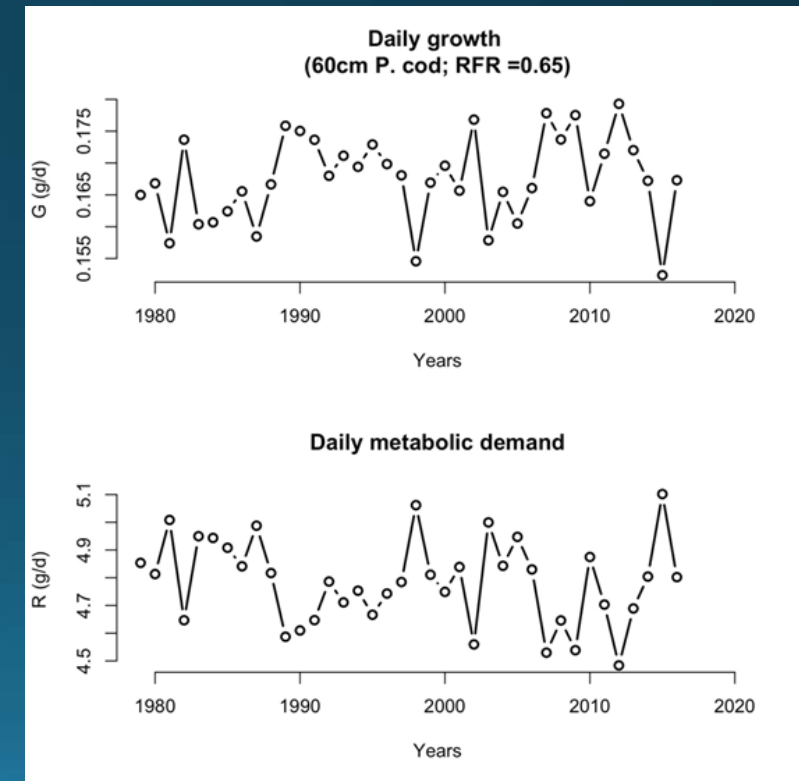
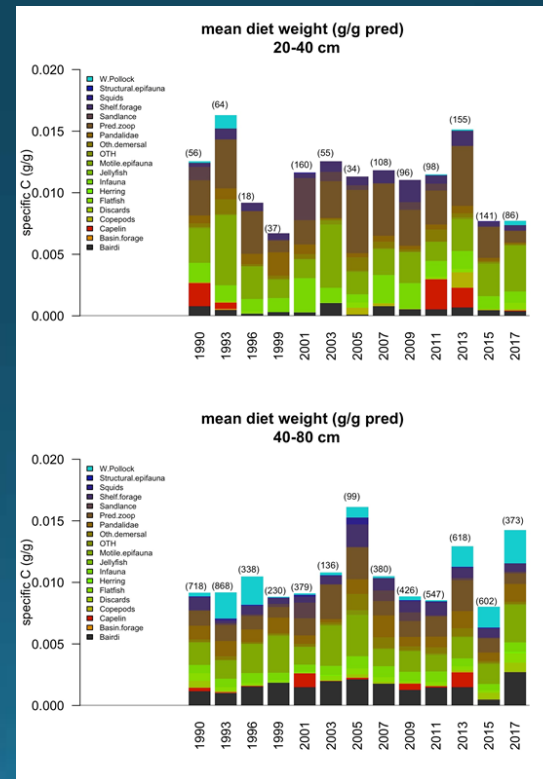
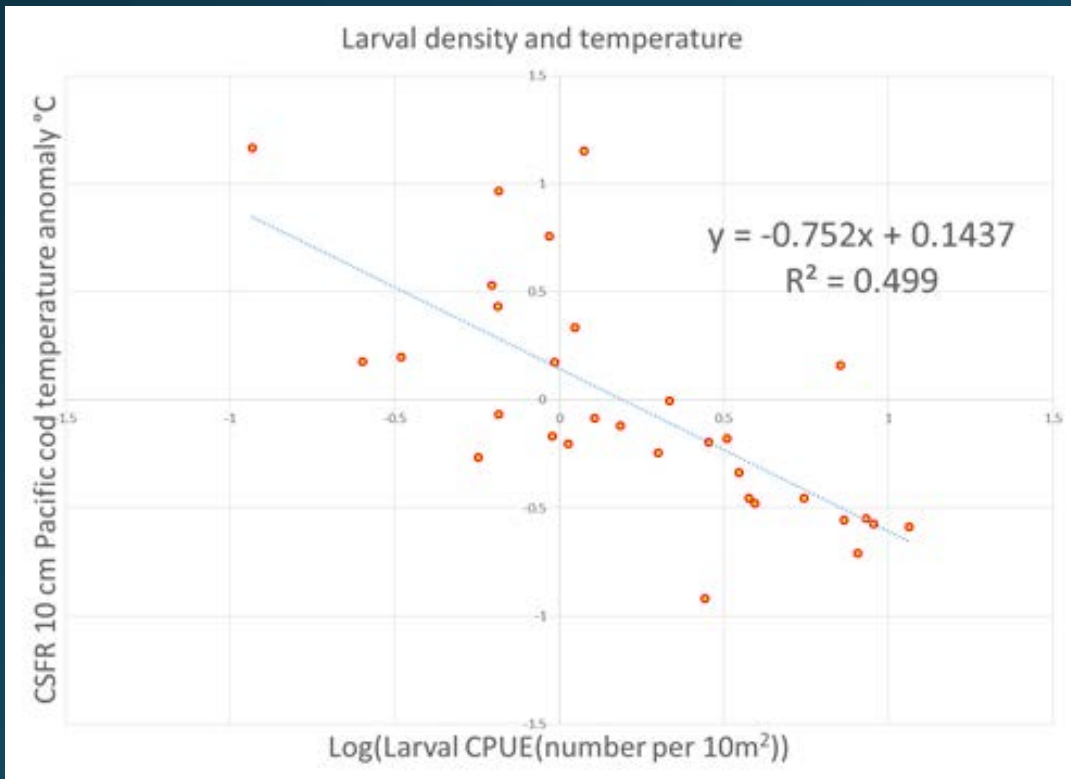


Analysis by Stephani Zador

GOA Pacific cod The Blob



- Likely substantial impact on Pacific cod recruitment and natural mortality



GOA Pacific cod Bio-energetics summary



- Warmer temperatures were throughout the year and water column
- Higher metabolism in warmer temps lead to higher forage requirements
- Indications of lower forage amounts in 2015-2016
- Combination likely lead to higher Pacific cod natural mortality for these years.

GOA Pacific cod Model fitting



- All models run in Stock Synthesis 3.24 U
- All models presented were found to converge ($< 1e-04$)
- All models “jitter” tested with CV of 0.15 on all fitted parameters and 50 runs

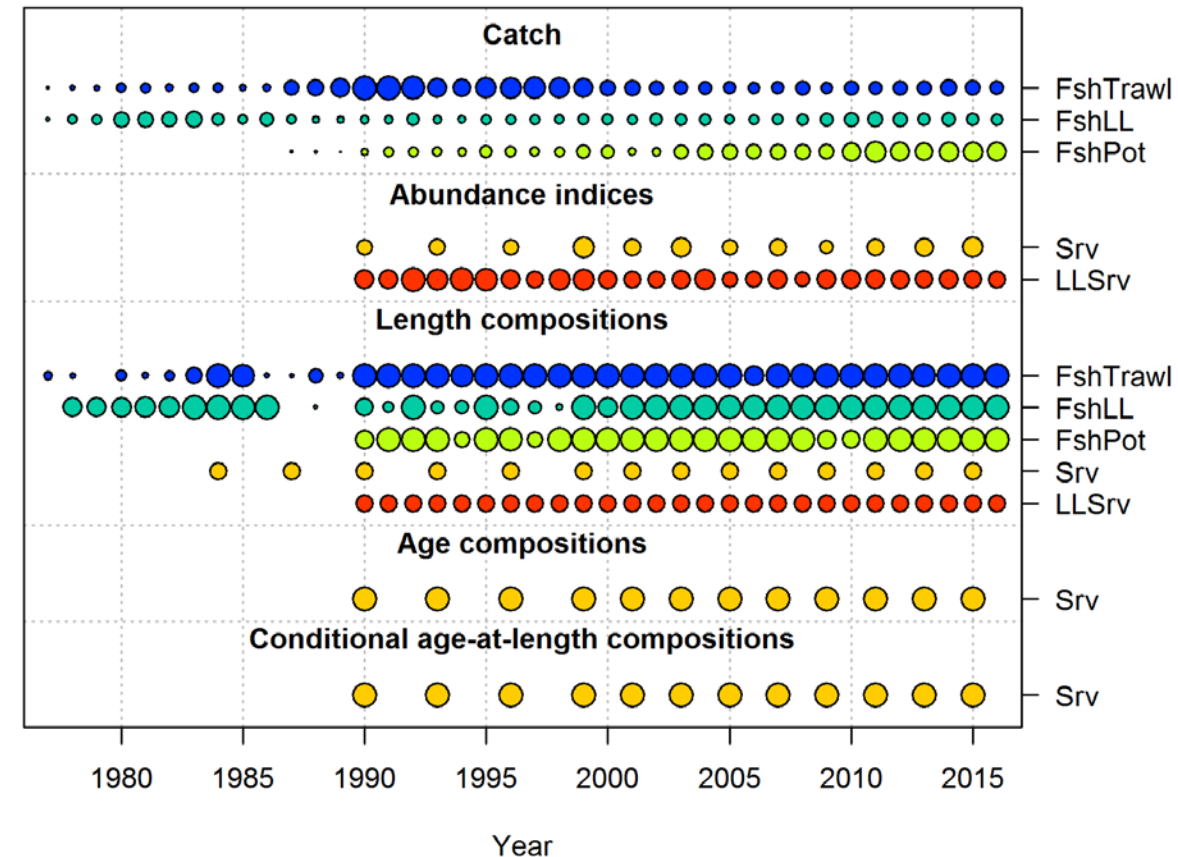
GOA Pacific cod

Base Model 16.08.25



- AFSC Bottom trawl survey
 - Abundance Index
 - Length and age composition
 - Conditional age-at-length
- AFSC longline survey
 - RPN index
 - Length composition
- Fisheries data with single season
 - Three fisheries (trawl, longline, pot)
 - Total catch
 - Length composition

Data by type and year, circle area is relative to precision within data type

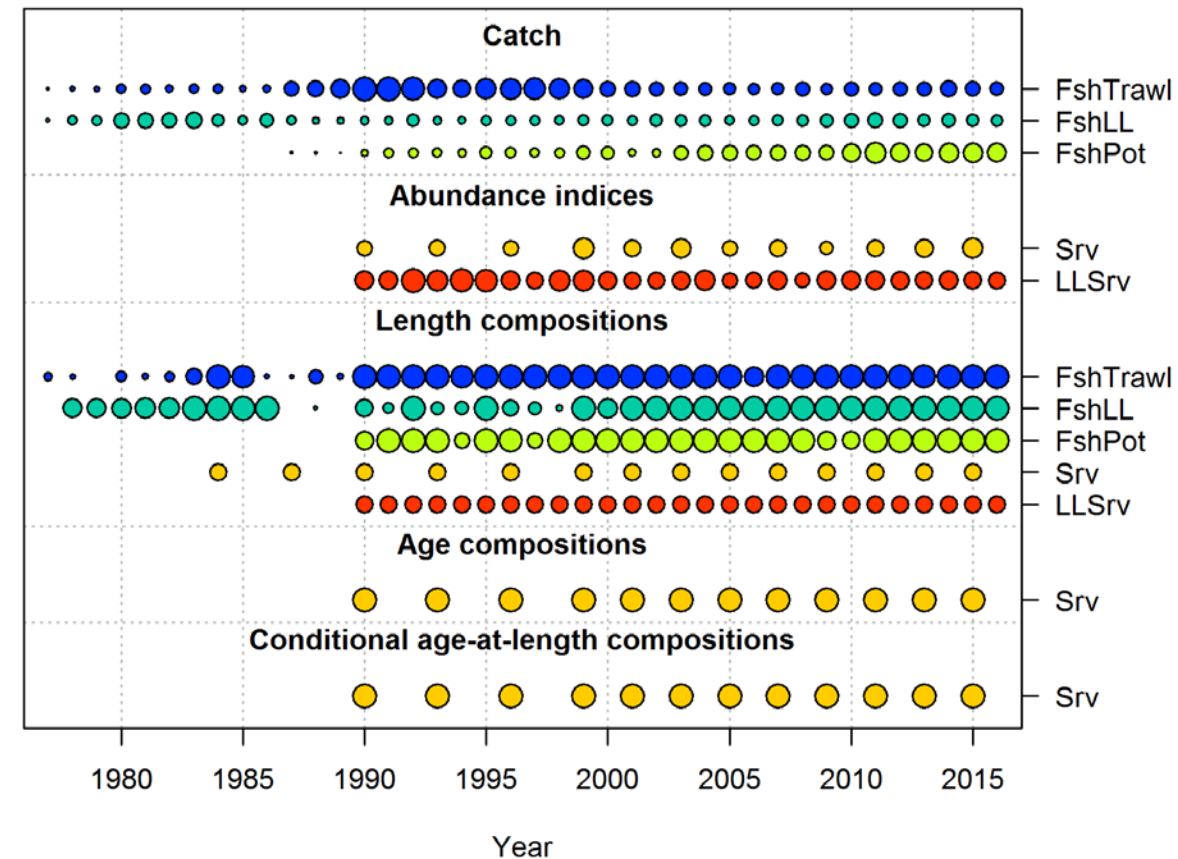


GOA Pacific cod Base Model 16.08.25



- Length and age composition fit as multinomial
 - Surveys sample size =100
 - Fishery sample size was the number of hauls or 200 whichever was smaller.

Data by type and year, circle area is relative to precision within data type



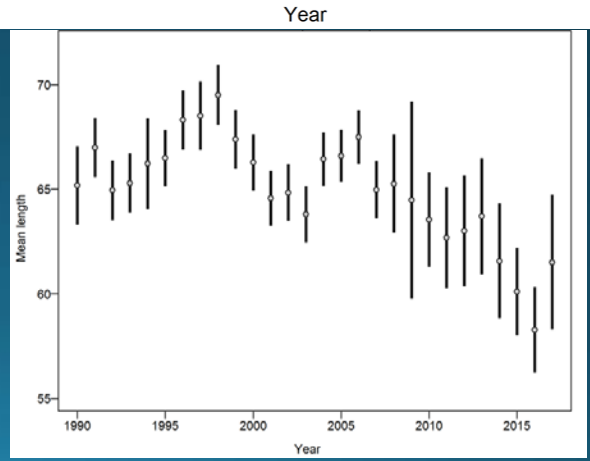
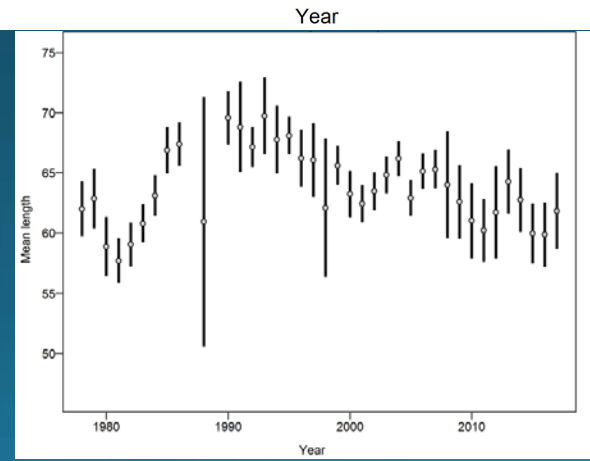
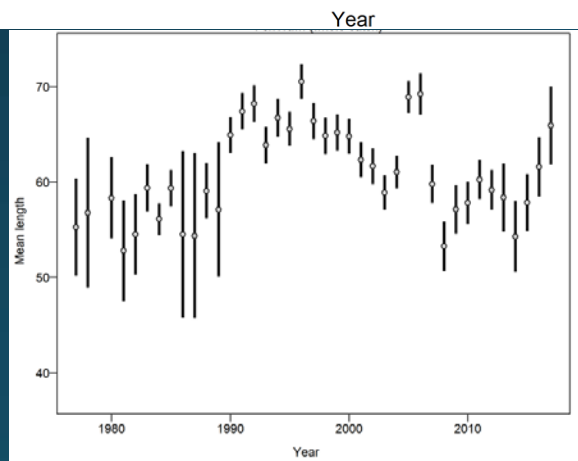
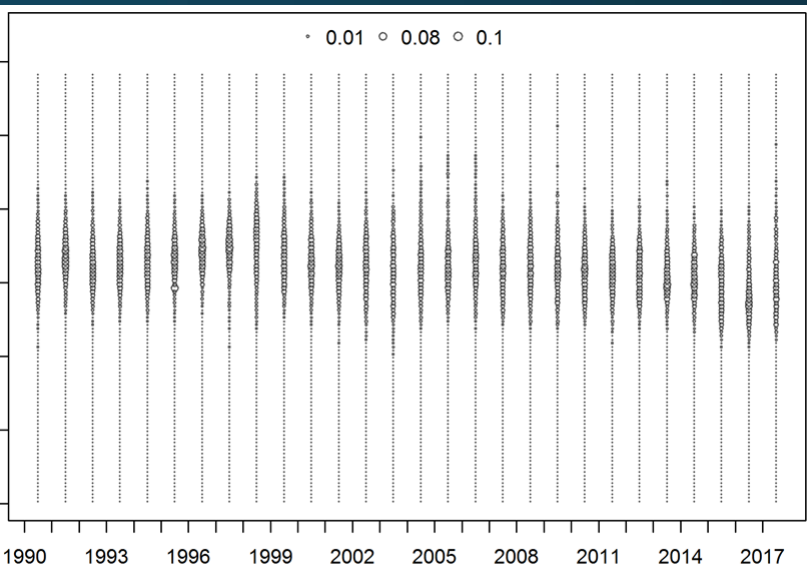
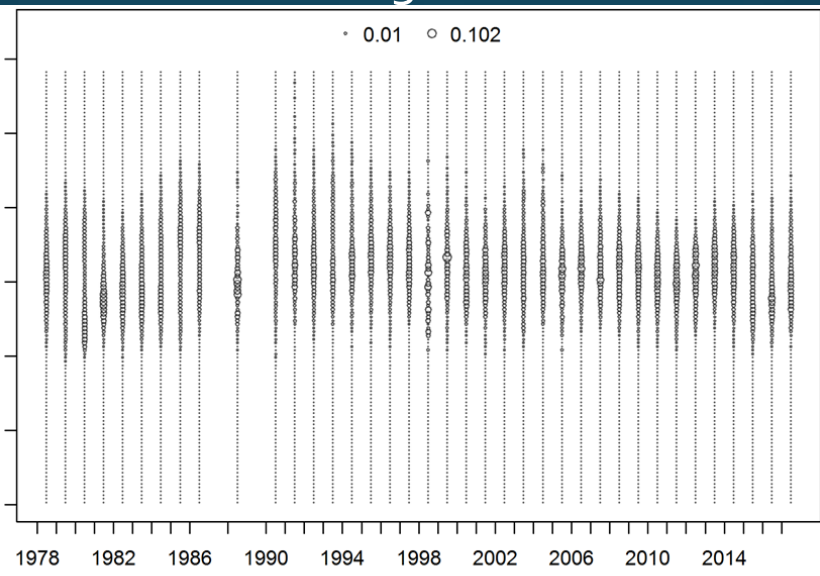
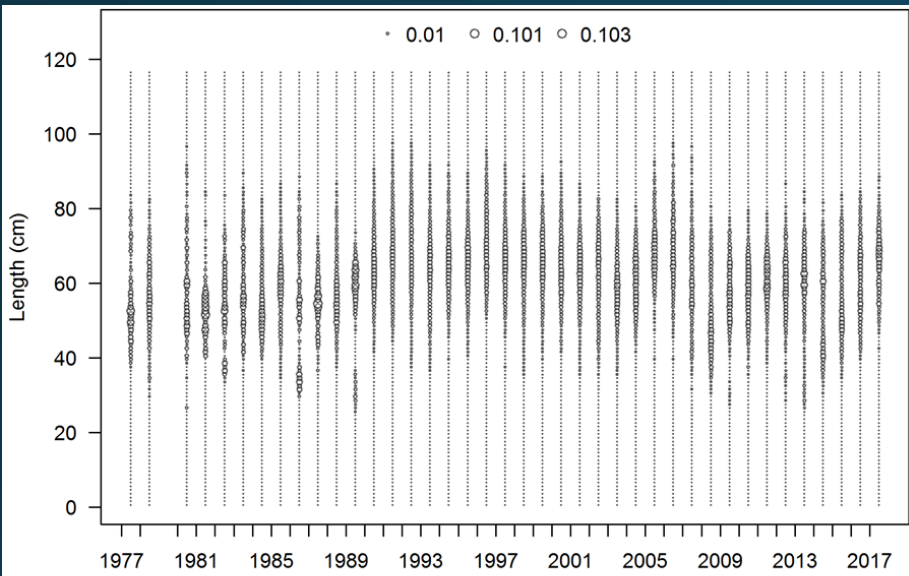
GOA Pacific cod Fishery length composition



Trawl

Longline

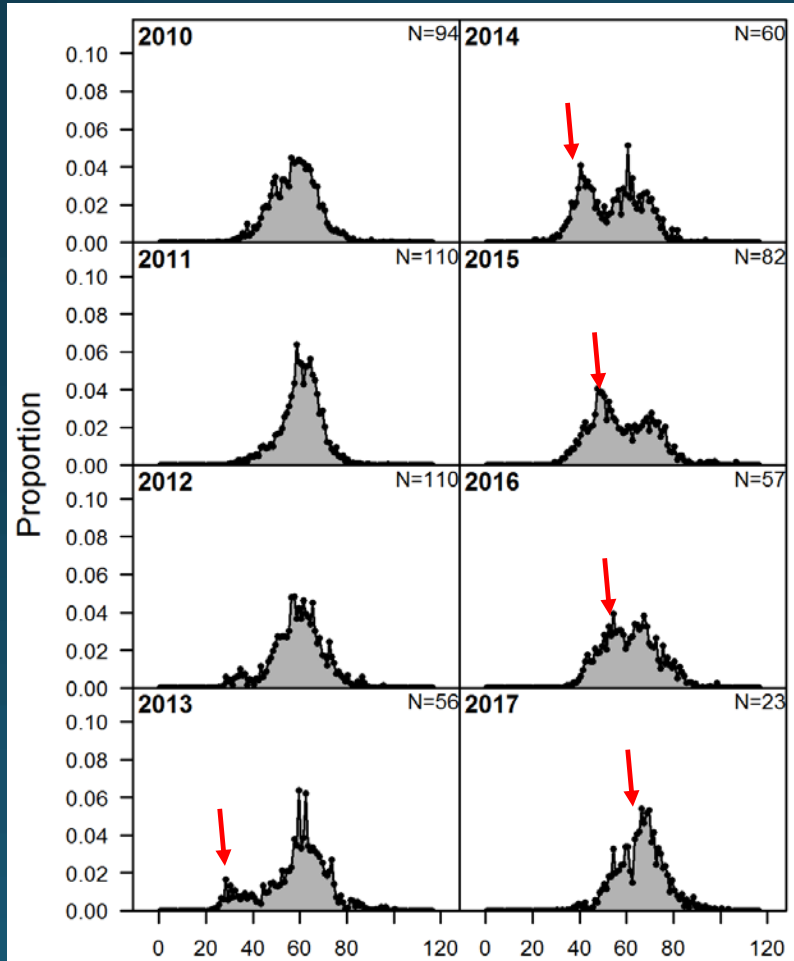
Pot



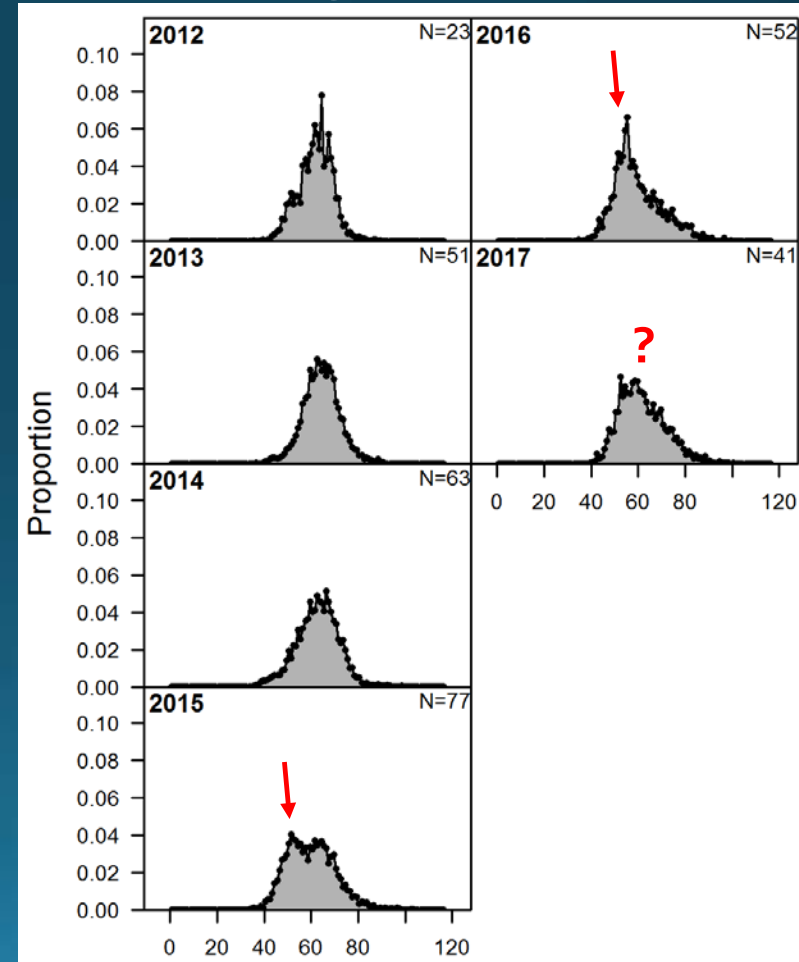
GOA Pacific cod Fishery length composition



Trawl fishery



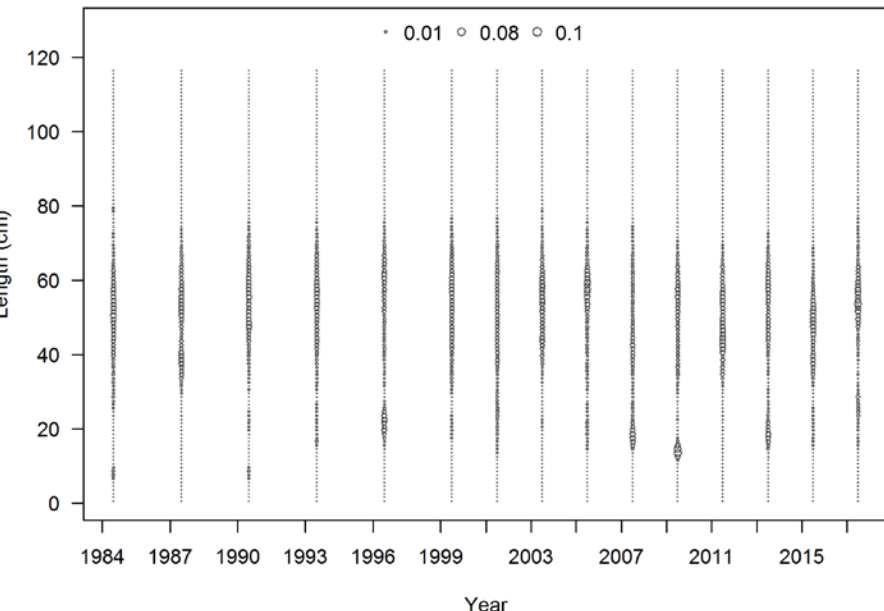
Longline fishery



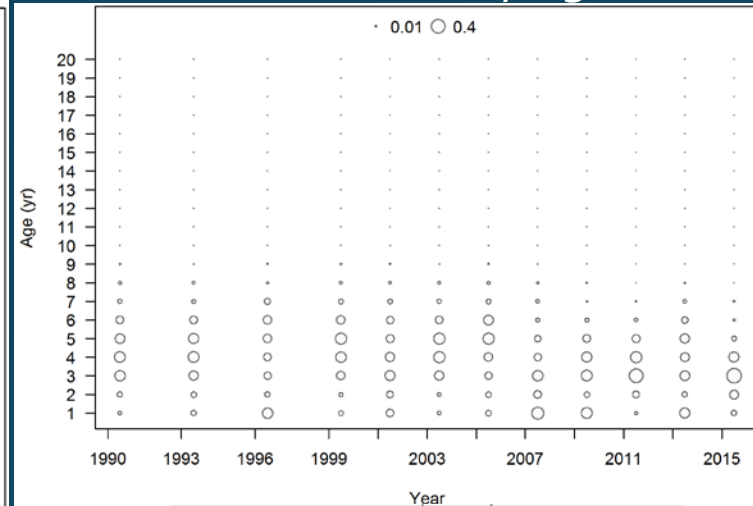
GOA Pacific cod AFSC survey length and age composition



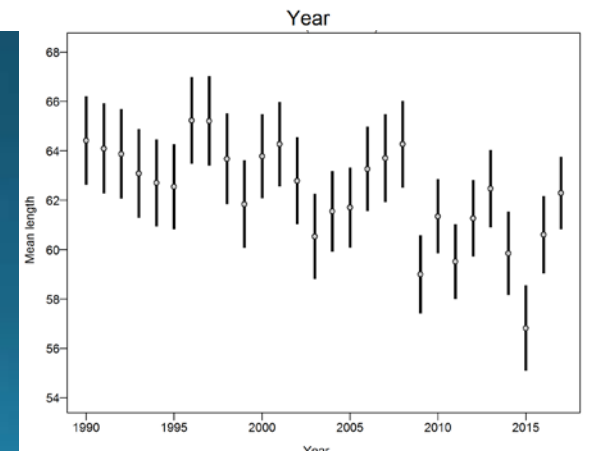
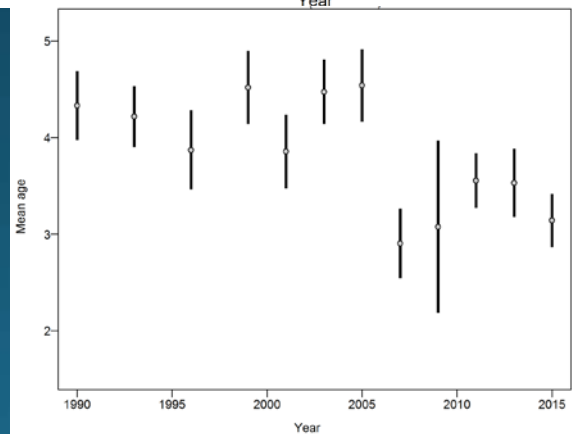
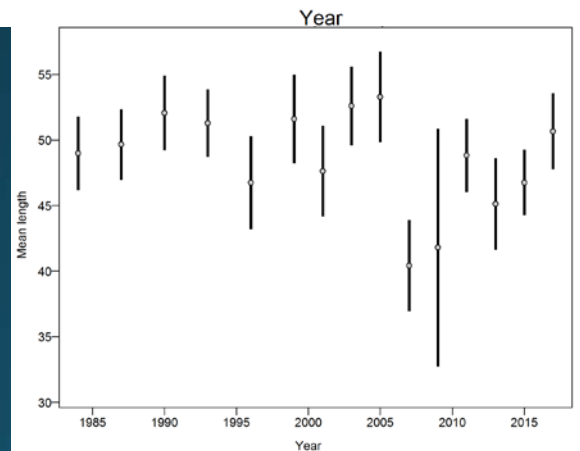
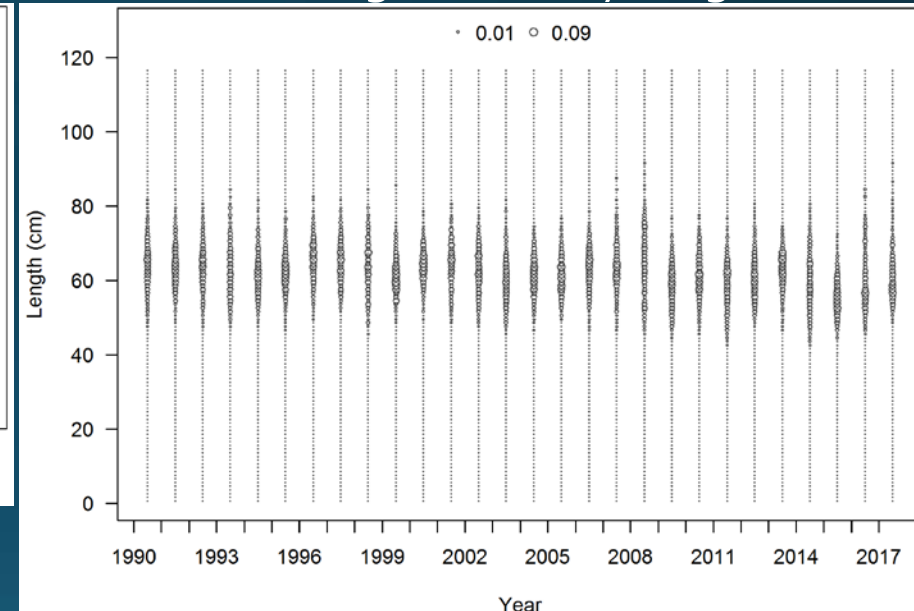
Trawl survey length



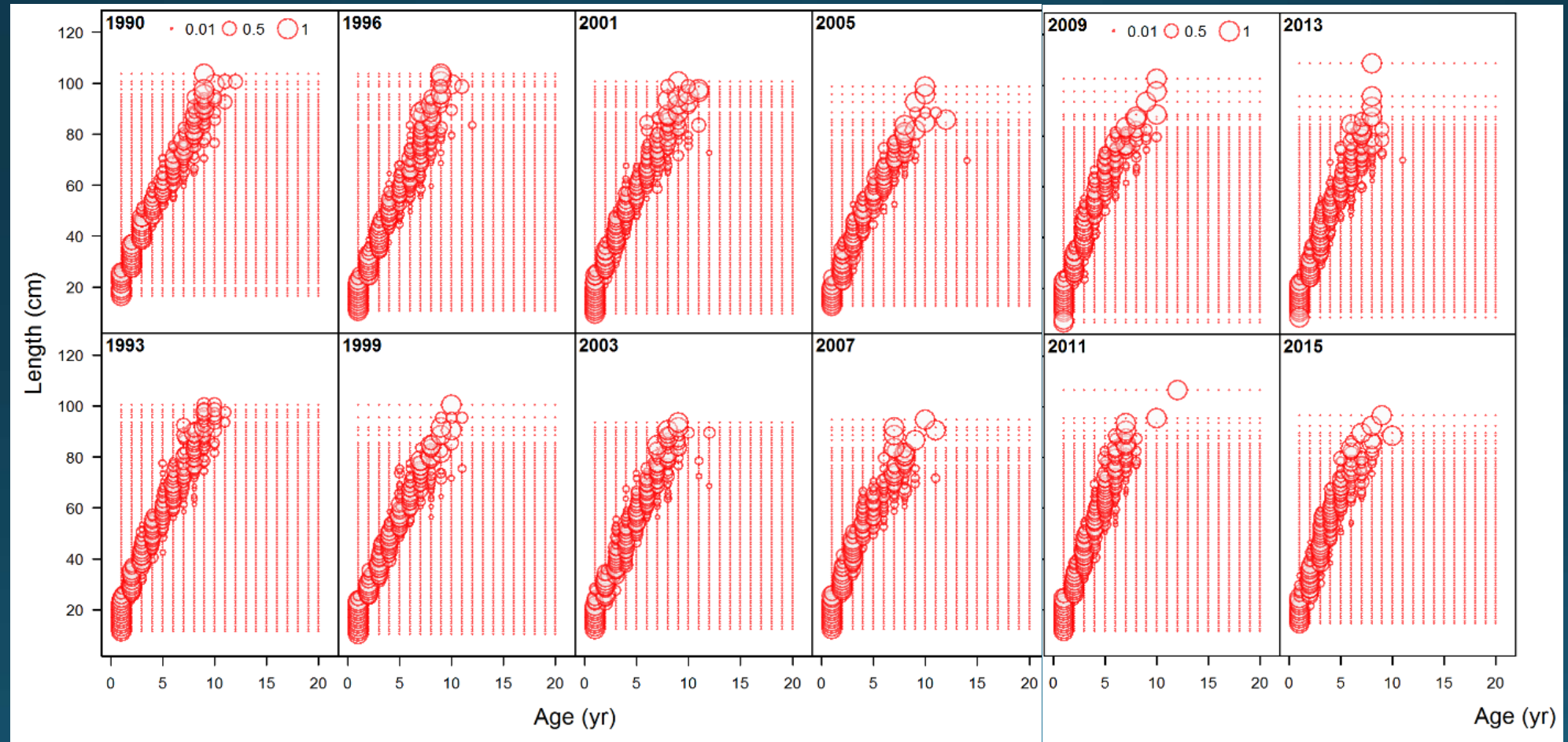
Trawl survey age



Longline survey length



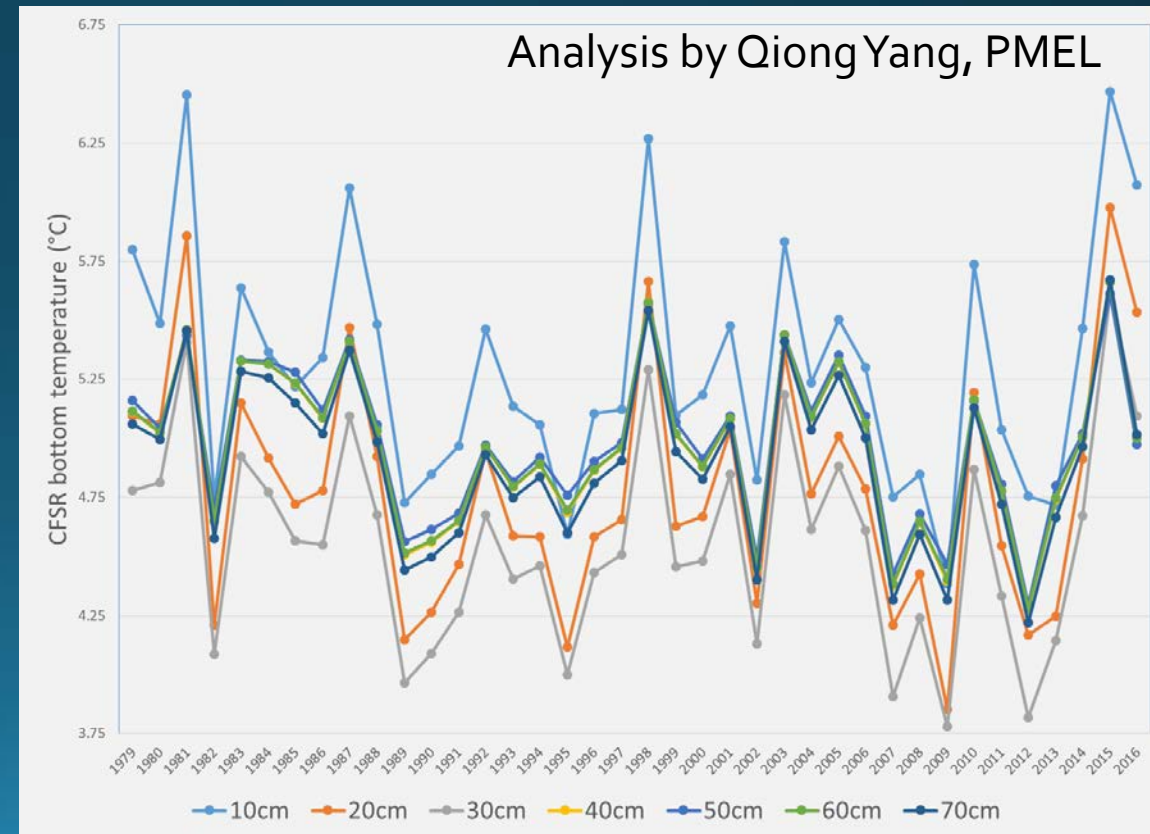
GOA Pacific cod Conditional length at age



GOA Pacific cod Environmental index

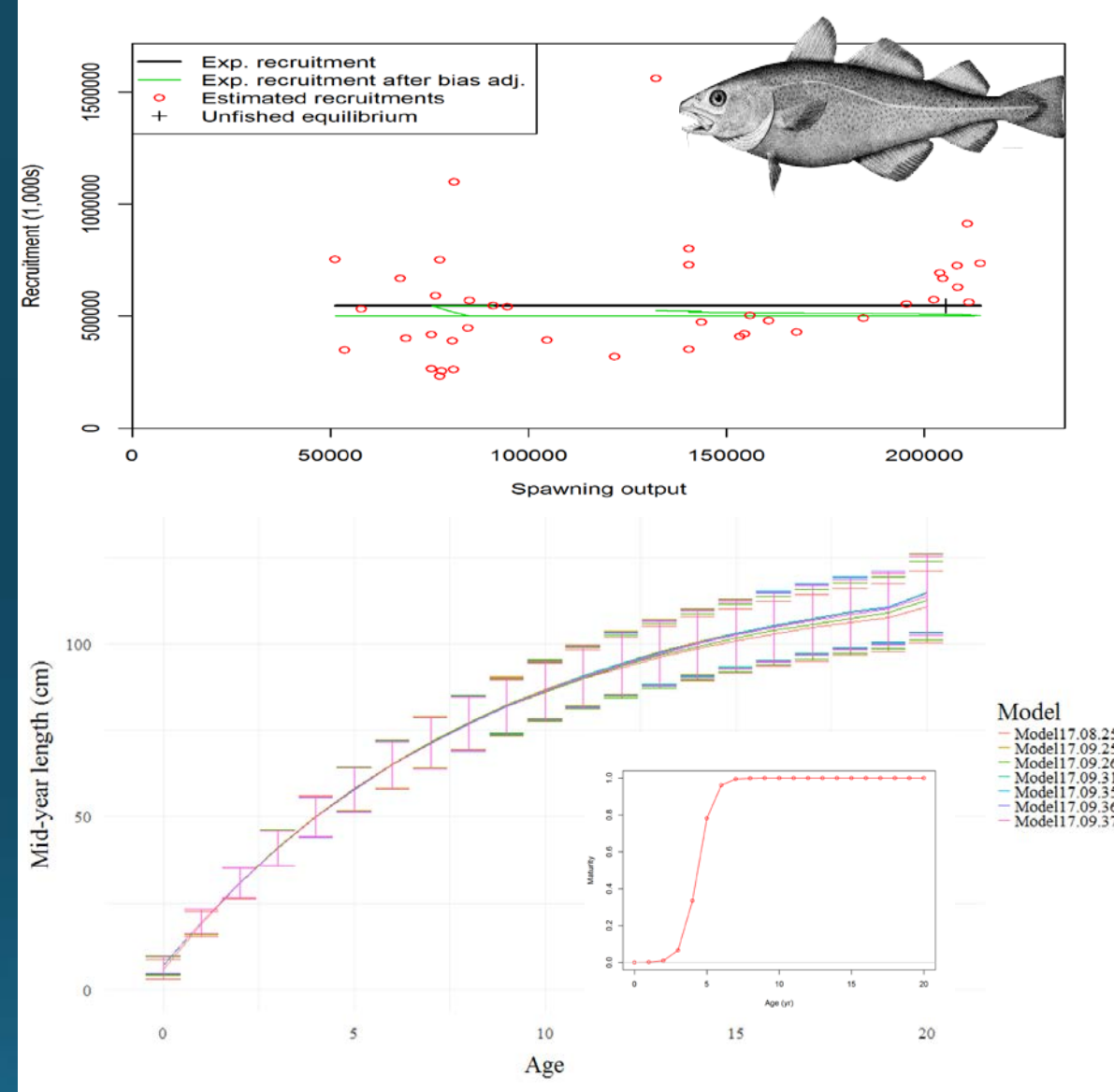


- Climate Forecast System Reanalysis (CFSR) water temperatures
 - Filter to bottom temperatures at the average depth of Pacific cod at length in grids containing AFSC bottom trawl stations in CGOA.
- 3.75 to 6.5 °C
- 2015 warmest year
 - peak warm 1981, 1998, 2014-2016
- 2009 coldest year
 - peak cold 1982, 1989, 2007-2009, 2012



GOA Pacific cod Base Model 16.08.25

- Beverton-Holt recruitment curve
 - Steepness = 1.0, Sigma R = 0.44
- Log normal M ($\mu = 0.38, \sigma = 0.1$)
- Catchability
 - Float for longline survey
 - Uniform prior on trawl survey Q
- Maturity based on Stark (2007)
 - $A_{50\%} = 4.3499$

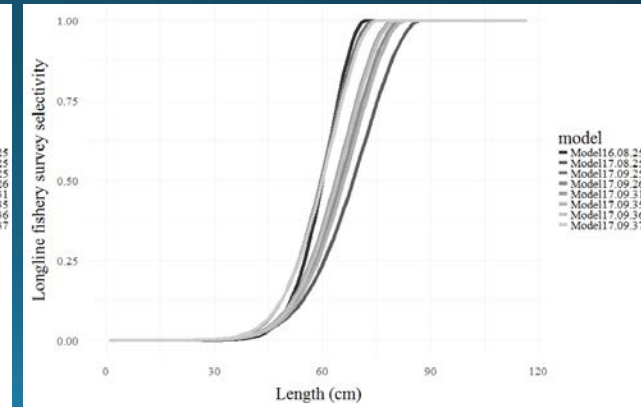
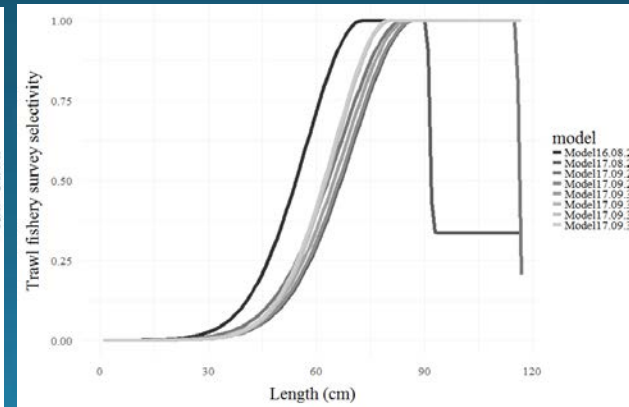
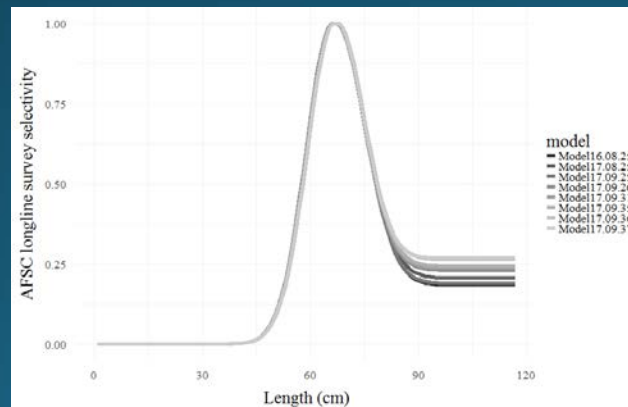
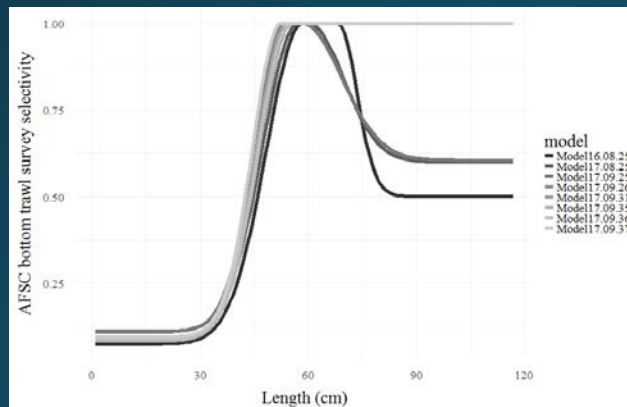
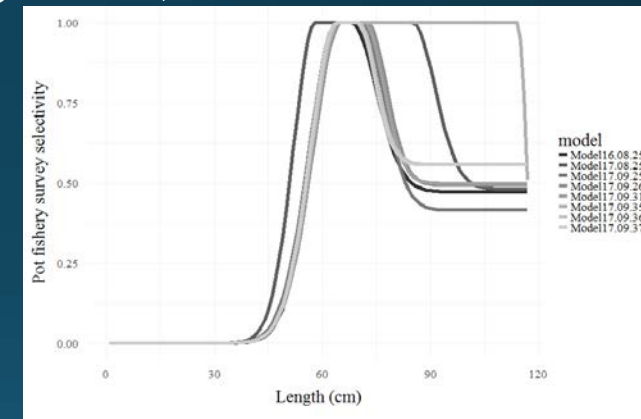


- Single growth model fit to conditional length at age from bottom trawl survey

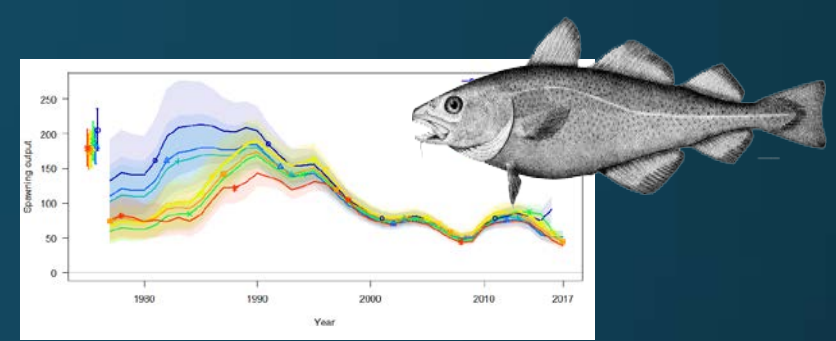
GOA Pacific cod Base Model 16.08.25



- All selectivity double normal on length composition
 - Allowed dome-shaped for all
 - Blocks on trawl and longline fishery (1977-1989,1990-2012,2013-2016)
 - Blocks on pot fishery (1977-2012,2013-2016)
 - Blocks on trawl survey (1984-1995,1996-2005,2006-2016)
 - Longline survey single selectivity curve



GOA Pacific cod Model runs for 2018



Model 17.08.25 same as 2016 Model16.08.25

- Addition of 2017 trawl and longline surveys
- Addition of 2016 and 2017 fisheries catch and composition data

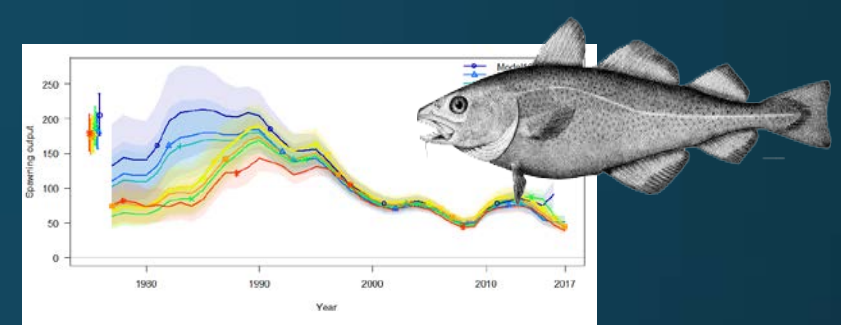
Data changes - Model 17.09.xx series – **Presented in September**

- New method for proportioning fishery length composition data
- ADFG port sampling for some pot fishery year/trimester/area

Model changes

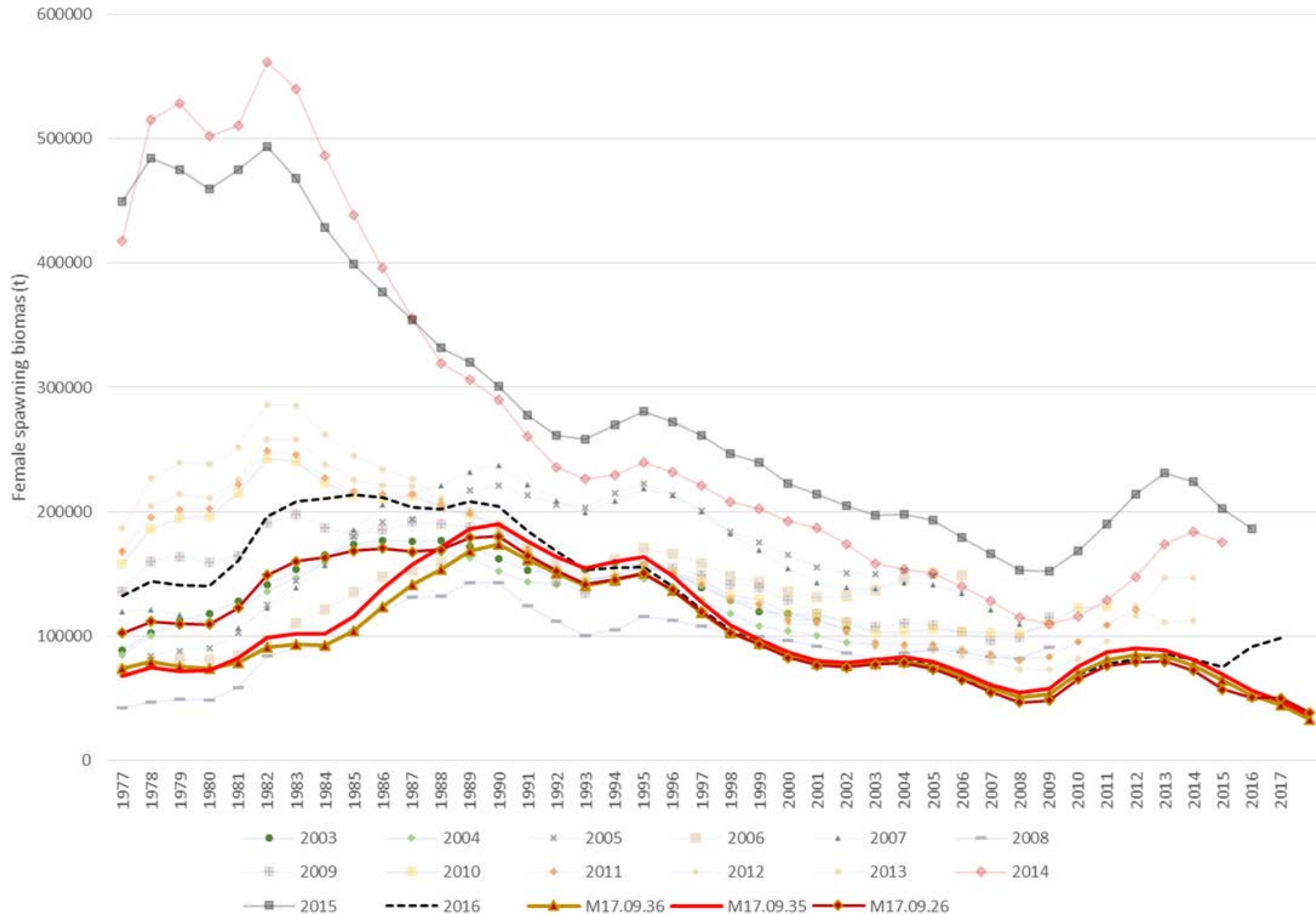
- 2015-2016 block on M
- Varying selectivity for trawl and longline fishery for 1977-1989
- Longline survey catchability conditioned on temperature
- New block on trawl and longline fishery selectivity for 2005-2006
- Francis T.A18 method for model tuning
- M conditioned on temperature

GOA Pacific cod Model runs for 2018

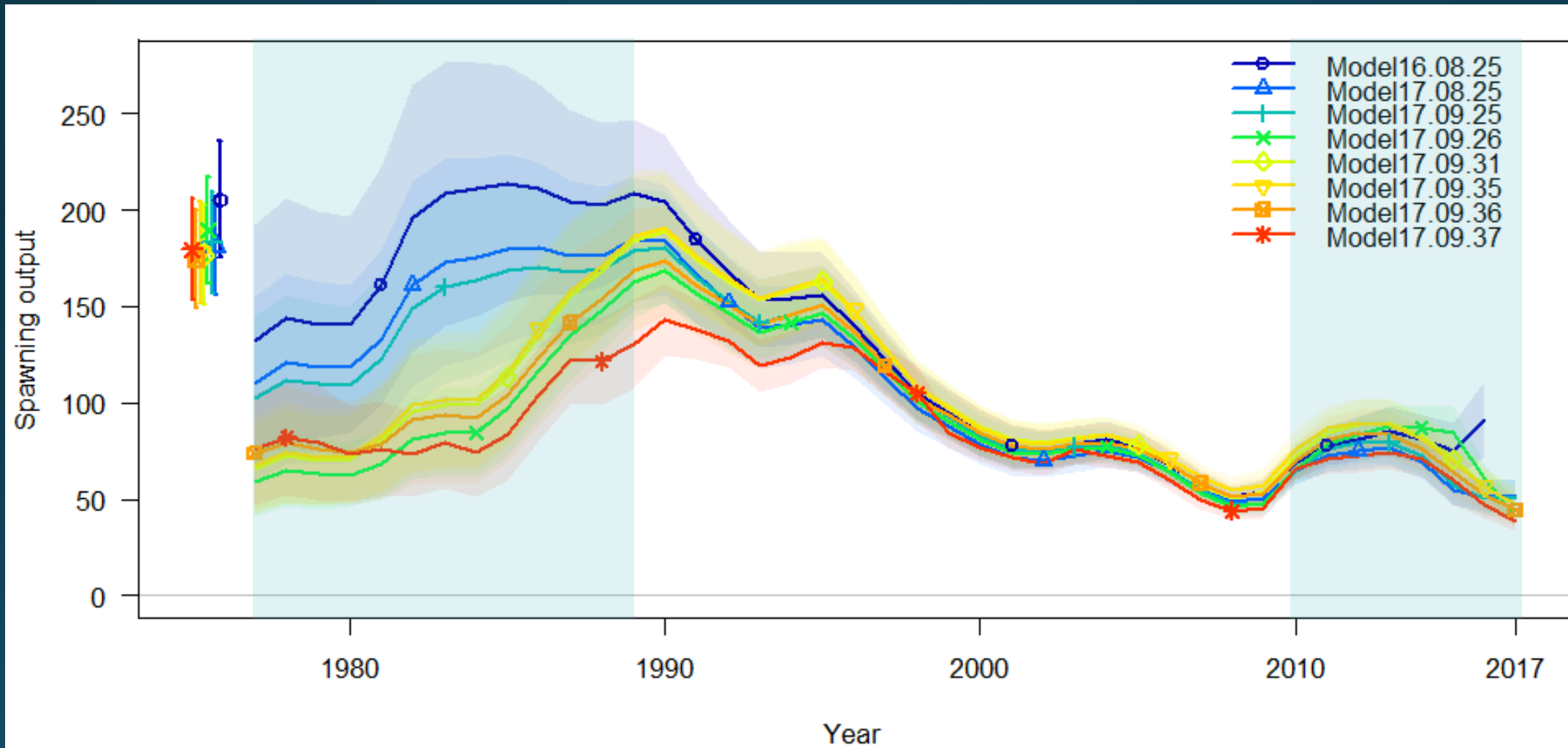


Models	Natural mortality	Survey catchability	Length-based Selectivity
17.08.25 last year's model with 2017 data	Fit with normal prior of 0.38 and $\sigma = 0.1$	Trawl fit with uniform prior Longline float	Blocked time varying selectivity dome-shaped allowed for all but the longline fishery. Longline and trawl: 1978-1989, 1990-2012, 2013-2016, and 2017 Pot: 1978-2012, and 2013-2017 Bottom trawl survey: 1984-1995, 1996-2005, 2006-2017
17.09.25	Fit with log normal prior $\log(\mu) = -0.81$ and $\sigma = 0.41$	Same as 17.08.25	Same as 17.08.25
17.09.26	Two blocks; 1977-2014 and 2017 and 2015-2016. Block 1: Fixed at 0.44 Block 2: Fit with log normal prior $\log(\mu) = -0.81$ and $\sigma = 0.41$	Same as 17.08.25	Same blocks as 17.08.25, except selectivity allowed to be fit annually for the 1978-1989 block based on parameter devs with CV = 0.2.
17.09.31	Same as 17.09.26, except both blocks fit with lognormal prior $\log(\mu) = -0.81$ and $\sigma = 0.1$	Trawl: Fit with uniform prior Longline: Fit with uniform prior and conditioned on temperature index with single uniform parameter	Same as 17.09.26
17.09.35 17.09.36 _(Francis tuned)	Same as 17.09.31	Same as 17.09.31	Same as 17.09.26, except added block for trawl and longline fisheries for 2005-2006

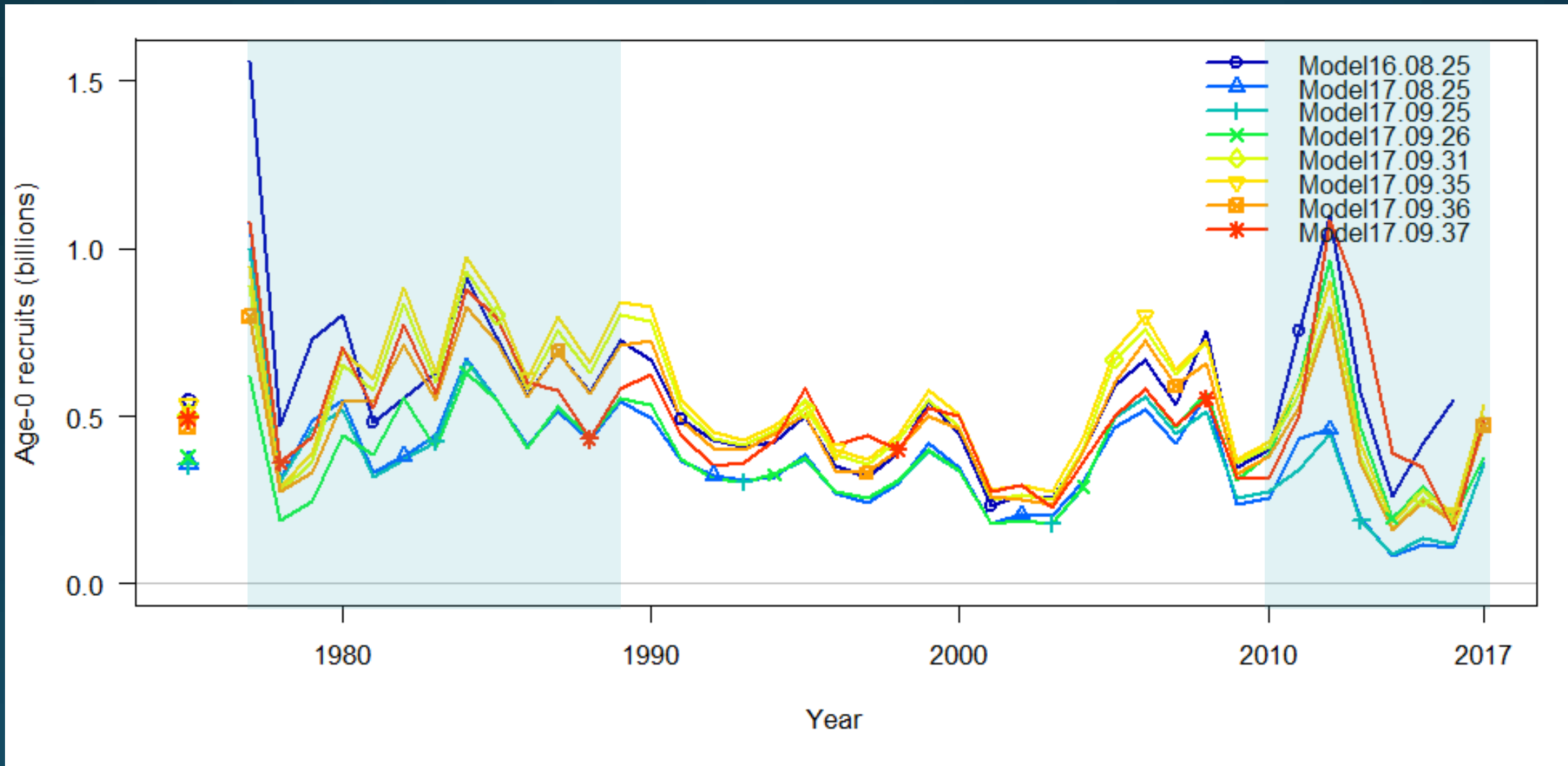
GOA Pacific cod models female spawning biomass by year



GOA Pacific cod- Model runs for 2018



GOA Pacific cod- Model runs for 2018



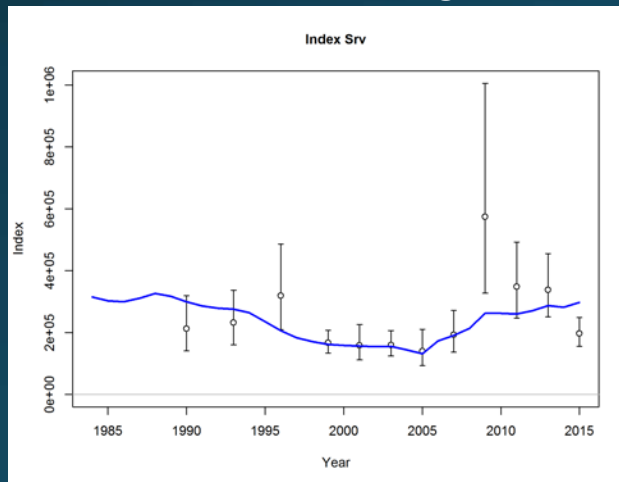
GOA Pacific cod

Data update: 16.08.25 vs. 17.08.25

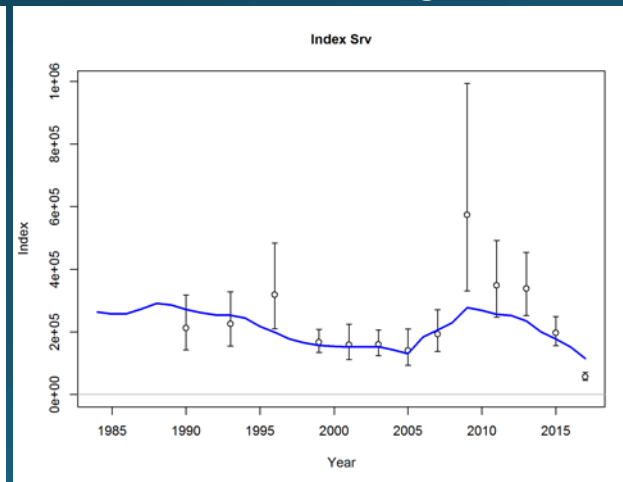


- Substantial differences in results
 - Influenced by 2017 trawl and longline survey index
 - Discounting 2011-2013 year classes
 - Increased residuals on survey and fishery length composition data
 - Decrease in M (0.47 to 0.44)

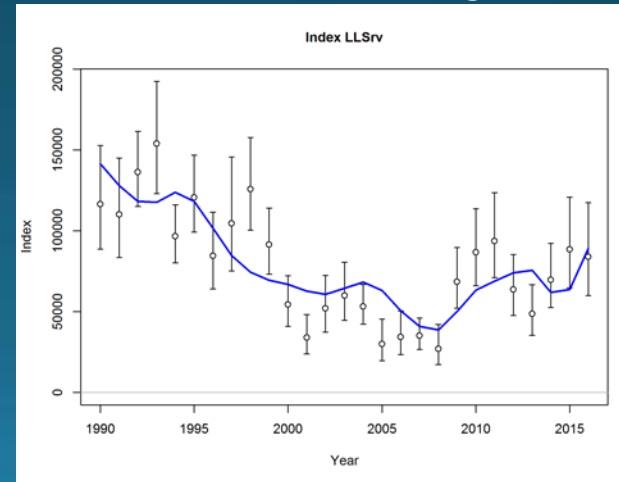
Model 16.08.05



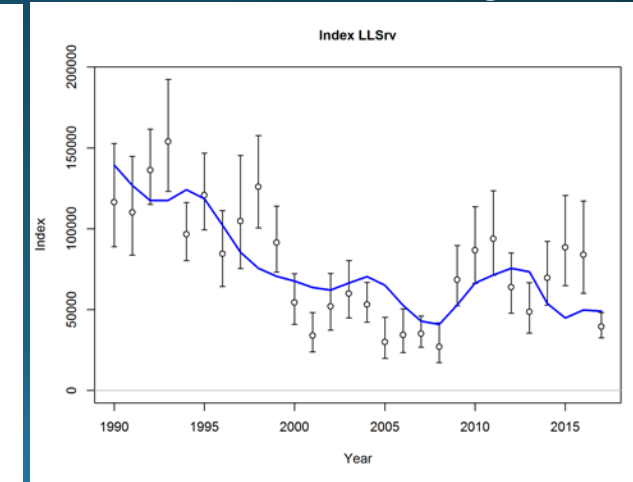
Model 17.08.25



Model 16.08.25



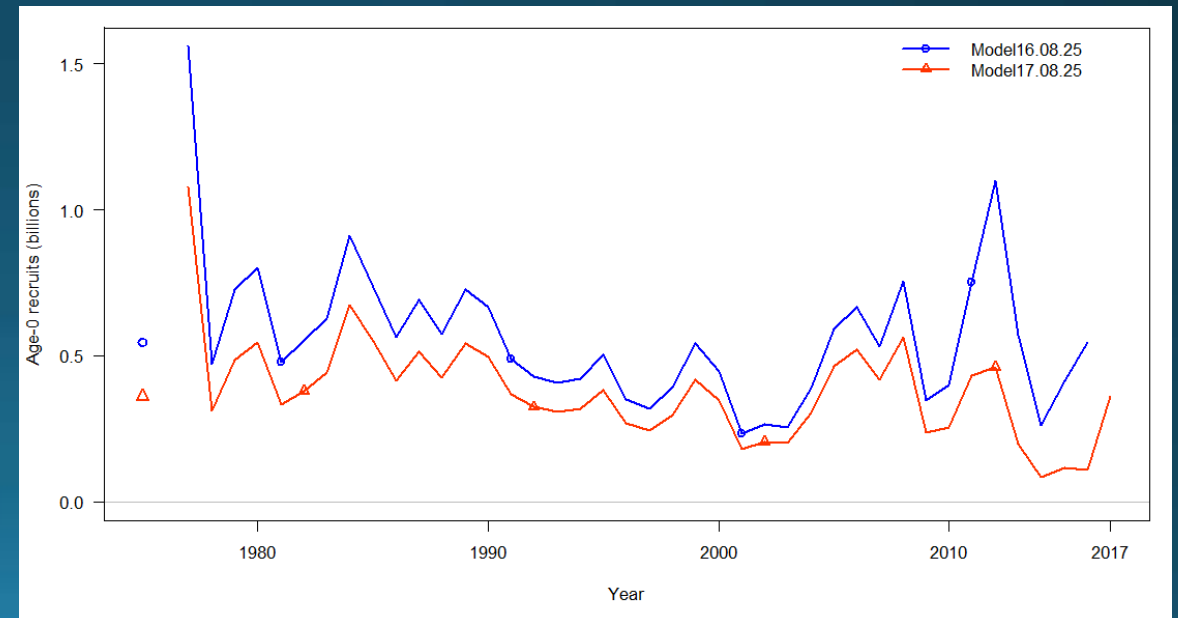
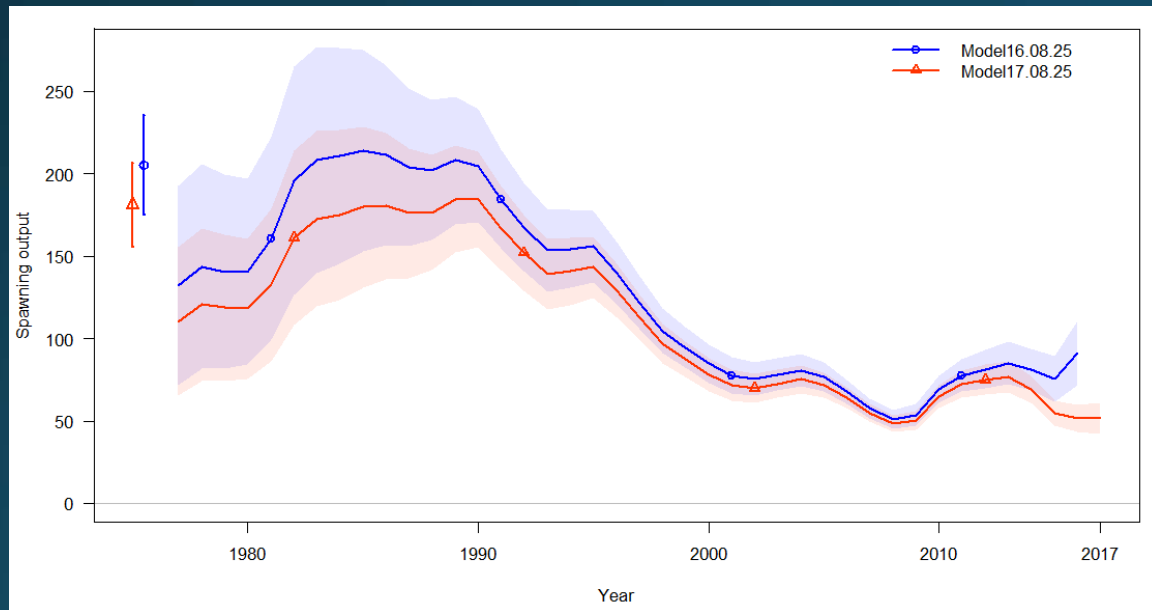
Model 17.08.25



GOA Pacific cod- Data update: 16.08.25 vs. 17.08.25



- Substantial differences in results
 - Influenced by 2017 trawl and longline survey index
 - Discounting 2011-2013 year classes
 - Increased residuals on survey and fishery length composition data
 - Decrease in M (0.47 to 0.44)

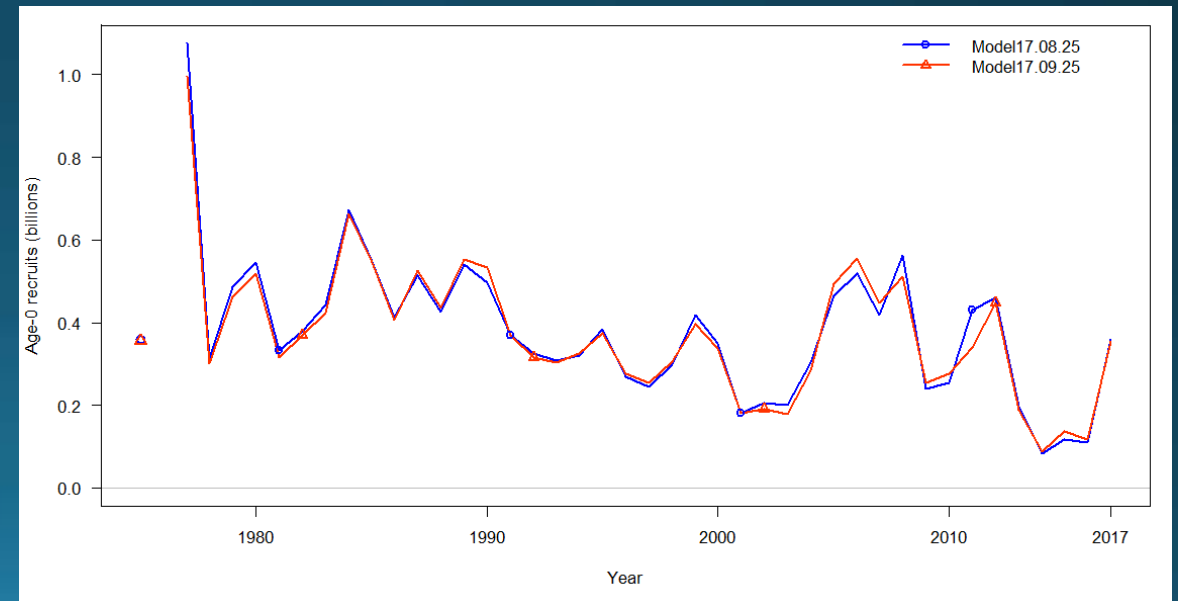
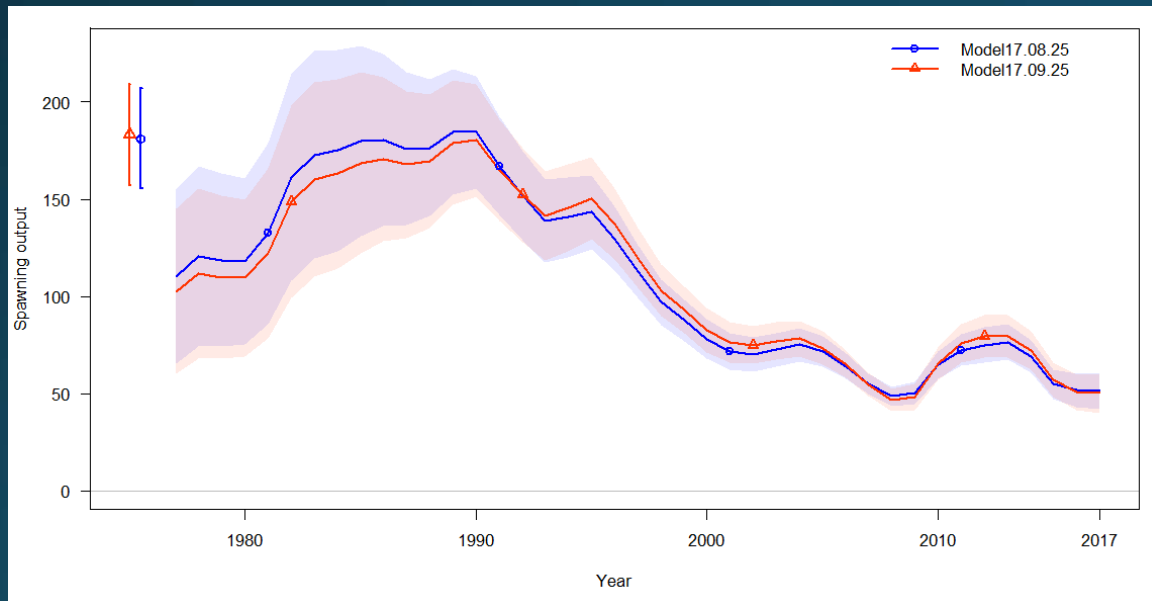


GOA Pacific cod

Data changes: 17.08.25 to 17.09.25



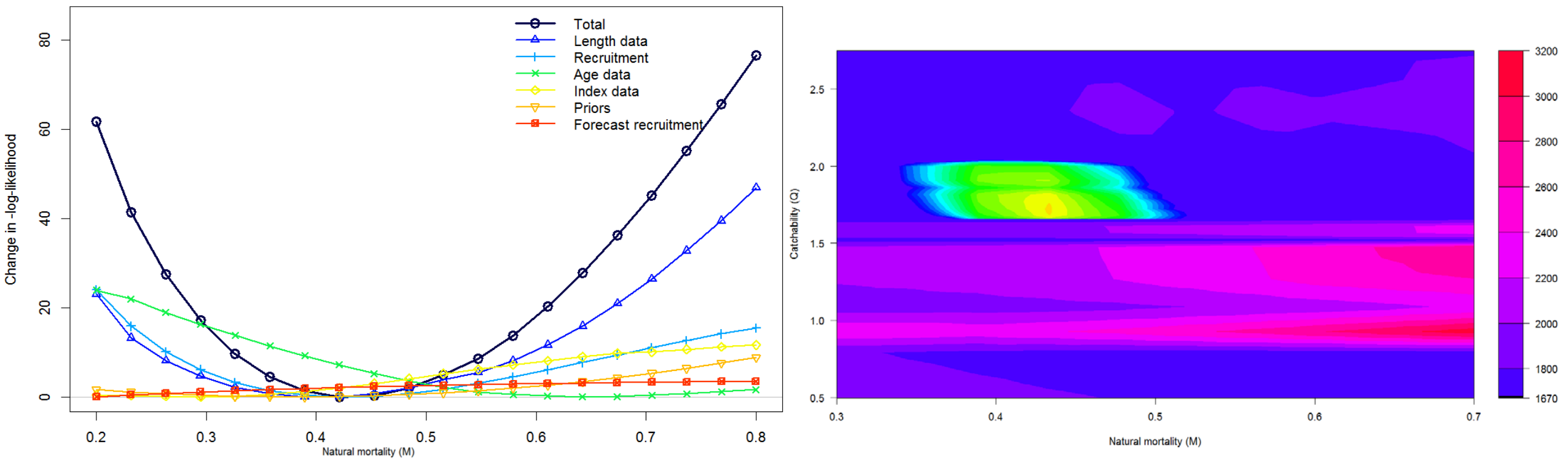
- Changes to fishery composition data proportioning
- Addition of ADFG port sampling for missing pot fishery data
- Small differences in model results
 - reduction of 1978 and 2011 year classes



GOA Pacific cod

Exploring Model 17.09.25

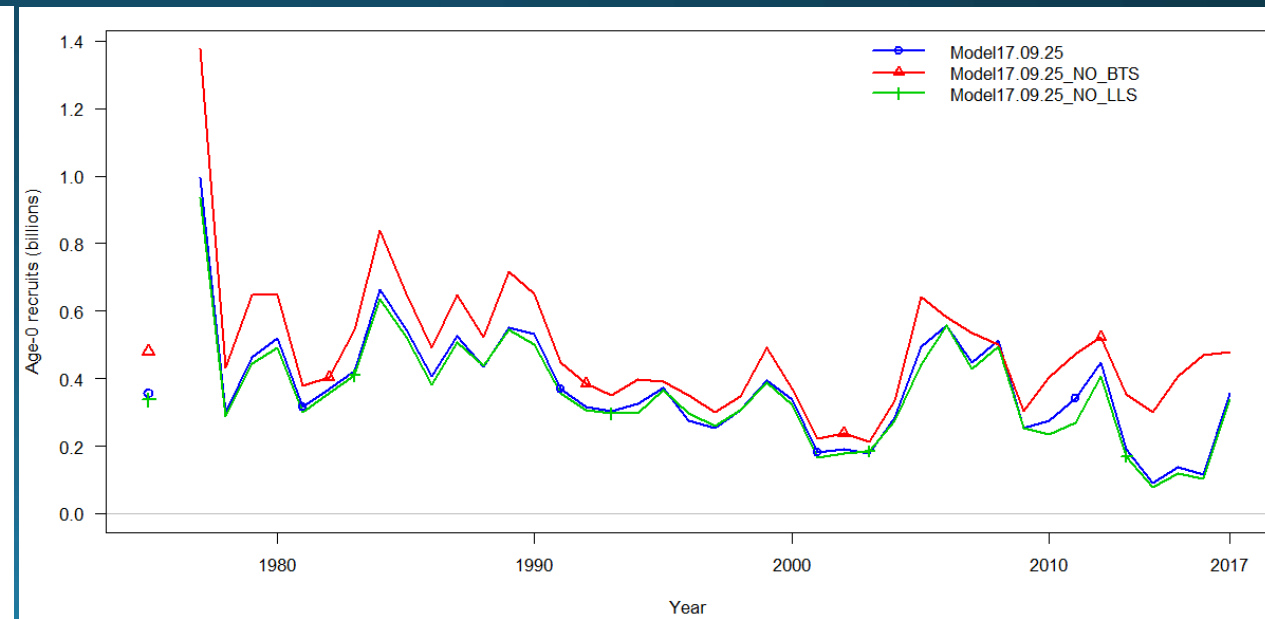
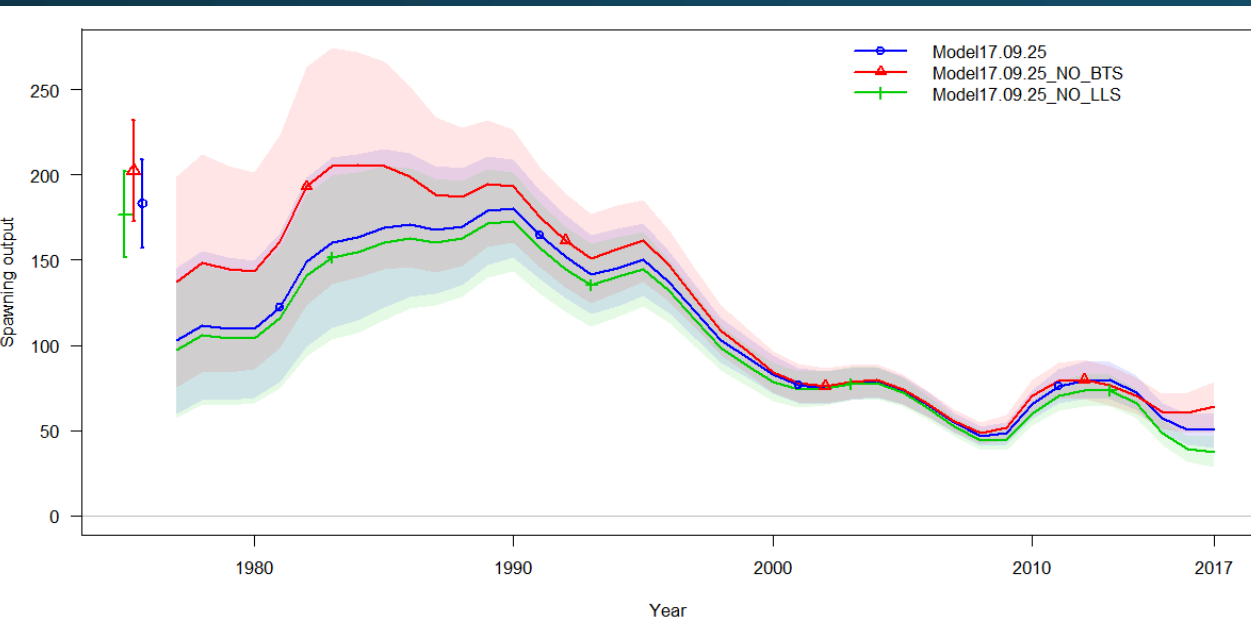
- Profiles over natural mortality and catchability
 - Natural mortality and catchability are well defined in this model



GOA Pacific cod

Exploring Model 17.09.25

- Results are sensitive to removal of AFSC bottom trawl survey
- Model is less sensitive to removal of AFSC longline survey data



GOA Pacific cod Fishery selectivity variable 1977-1989 and 2015-2016 block on natural mortality



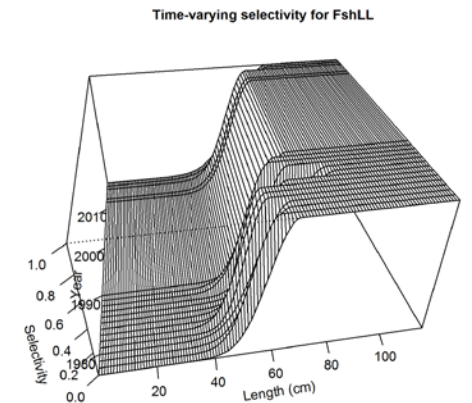
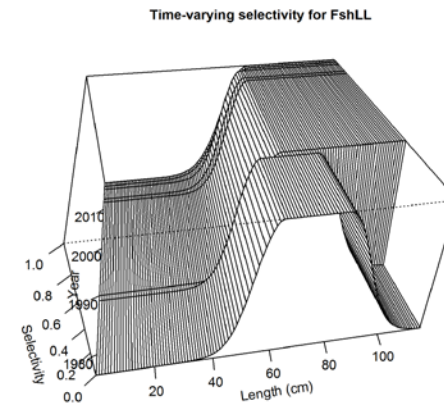
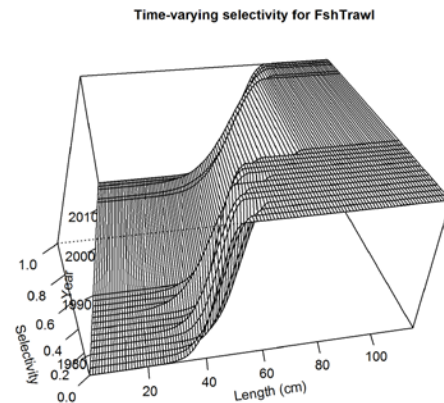
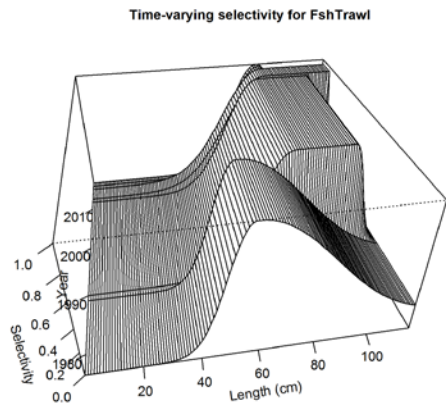
		Model17.09.25	Model17.09.25 W/Sel. change	Model17.09.25 W/M Block	Model17.09.26
	Parameters	134	191	135	192
Likelihoods					
	Total	1672.59	1624.40	1644.72	1598.34
	Survey	24.84	24.81	8.75	8.41
	Length Composition	1102.86	1052.32	1097.88	1047.31
	Age composition	547.62	538.96	545.91	538.34

Model 17.09.25

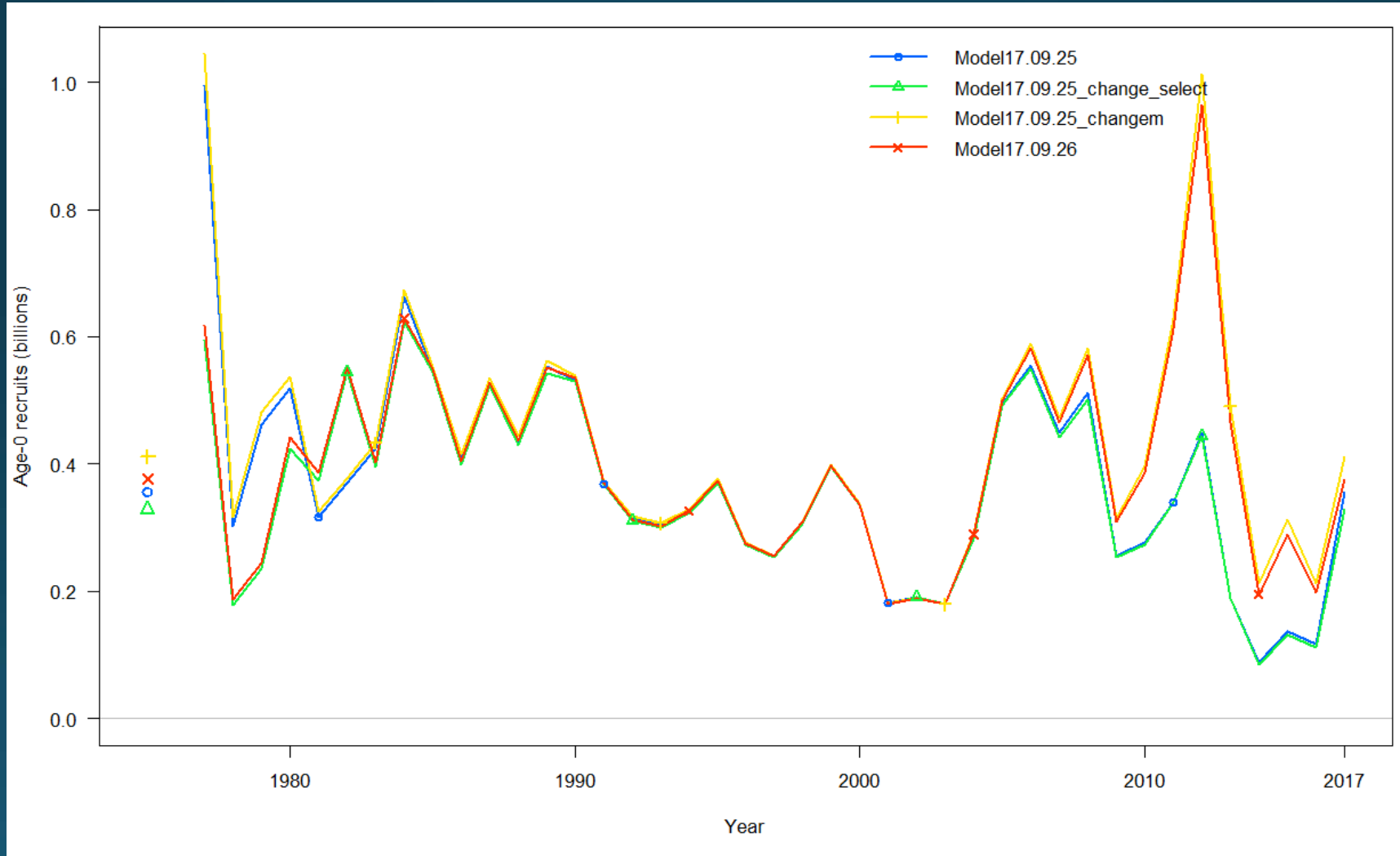
Model17.09.26

Model17.09.25

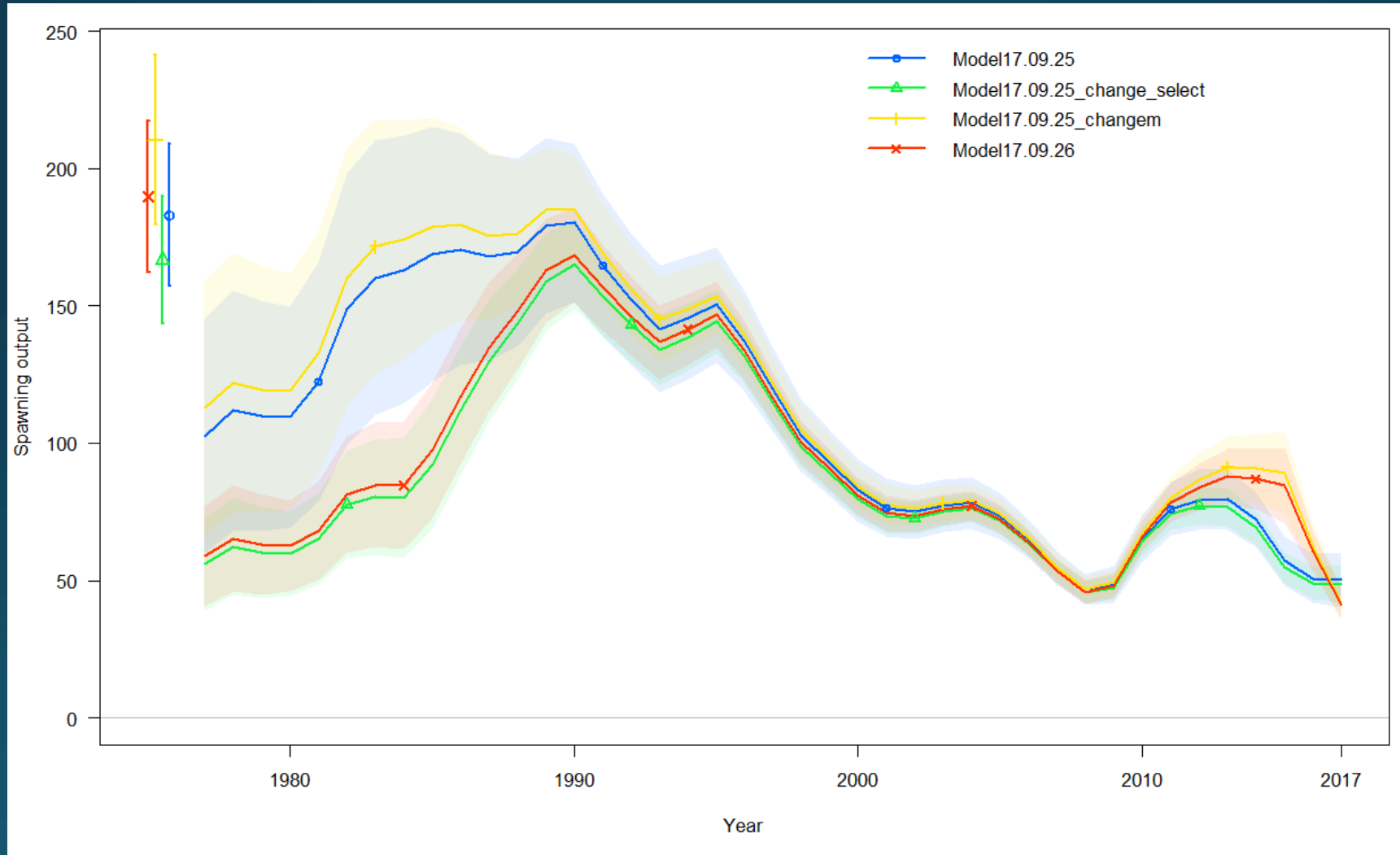
Model17.09.26



GOA Pacific cod Fishery selectivity 1977-1989 and 2015-2016 block on M



GOA Pacific cod Fishery selectivity 1977-1989 and 2015-2016 block on M



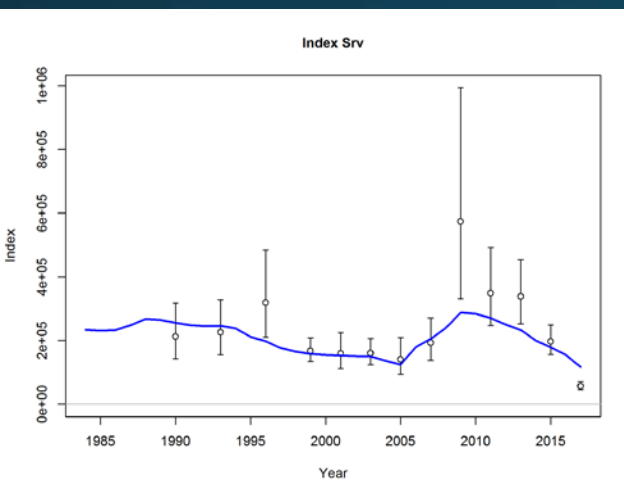
GOA Pacific cod

17.09.25 vs 17.09.26

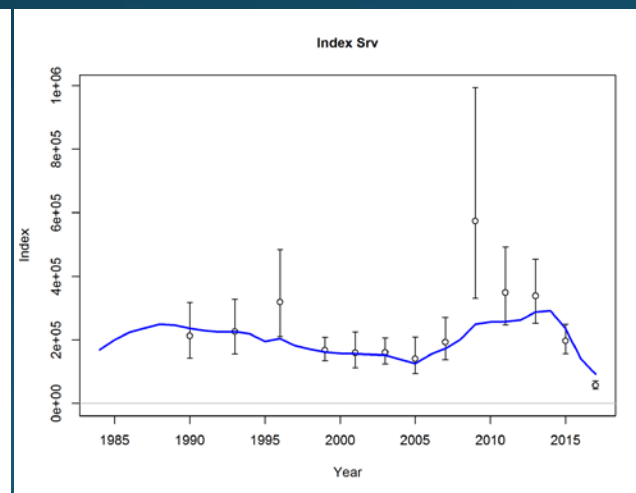


- Improvement to fits to AFSC bottom trawl and longline surveys
- Standard M is fixed at 0.44
- M for 2015-2016 block increased to 0.90

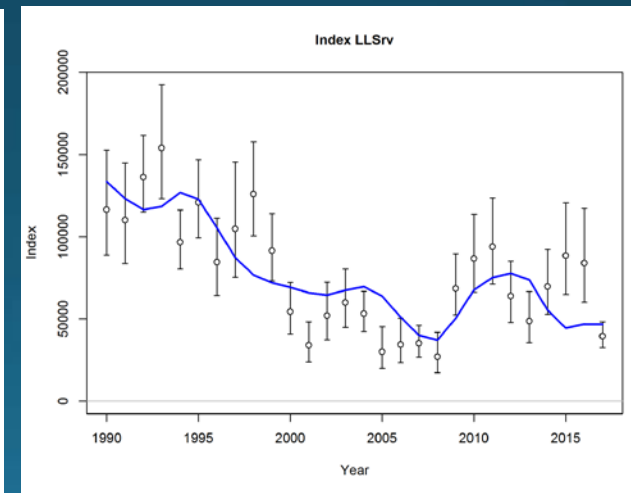
Model 17.09.25



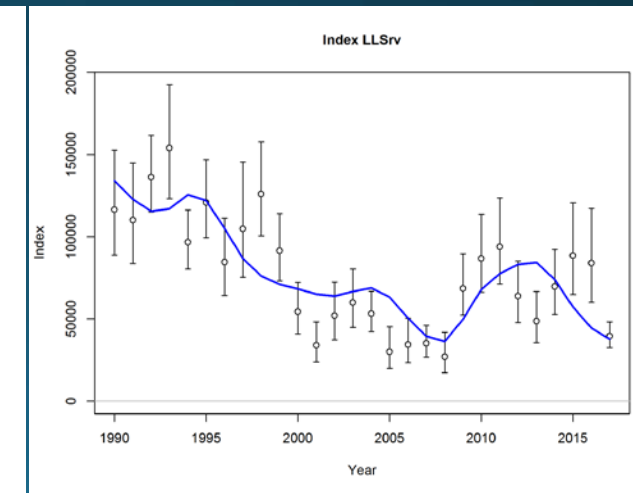
Model 17.09.26



Model 17.09.25



Model 17.09.26



GOA Pacific cod

17.09.25 vs 17.09.26



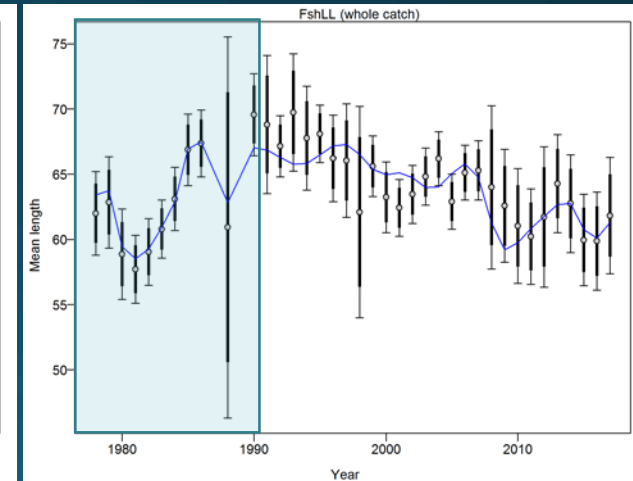
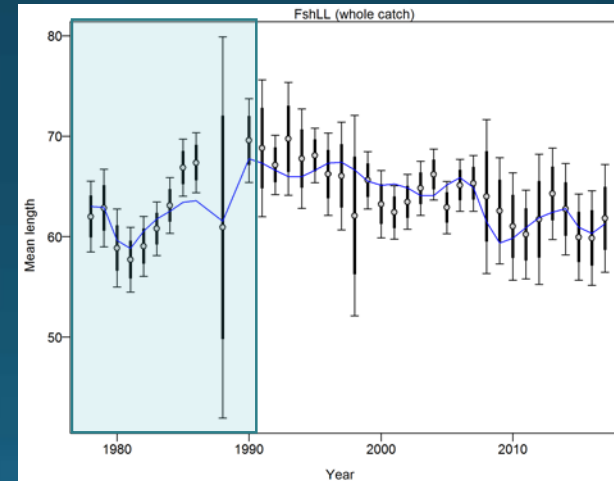
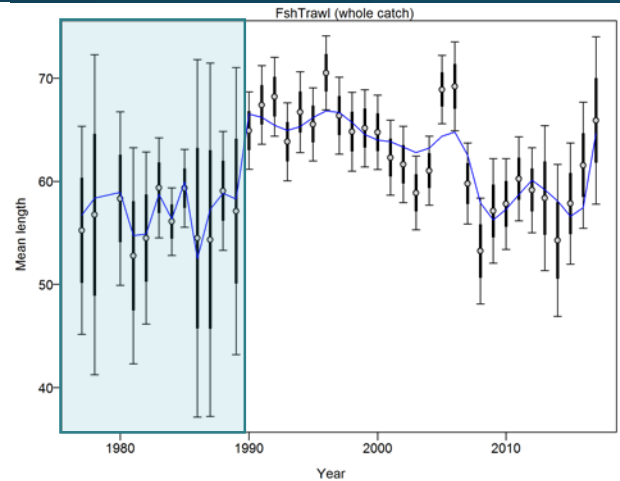
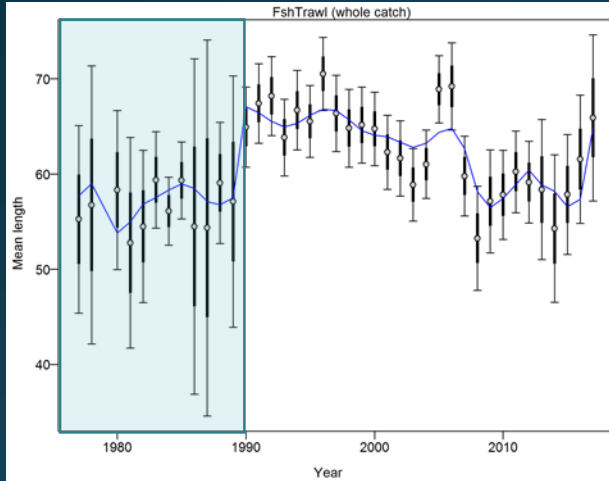
- Improvement to fits to 1977-1989 fishery length composition data

Model 17.09.25

Model 17.09.26

Model 17.09.25

Model 17.09.26

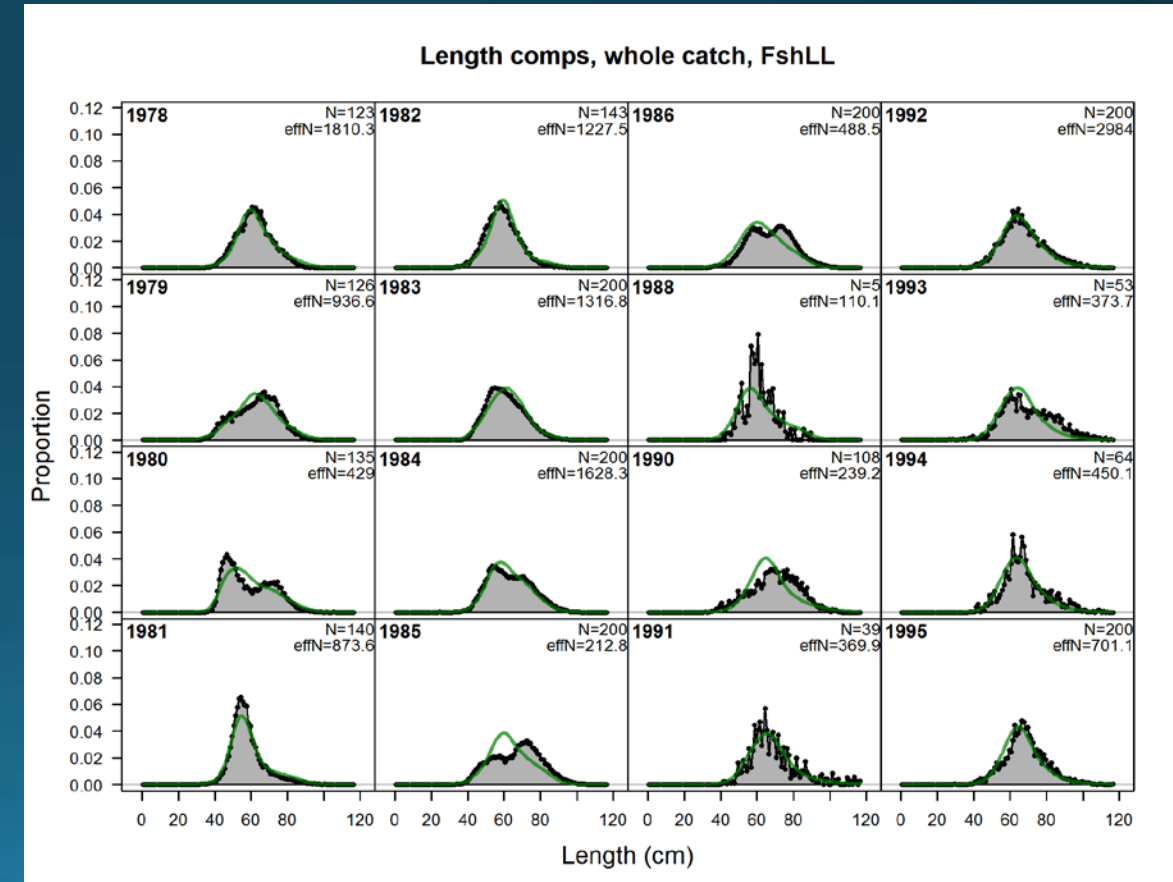
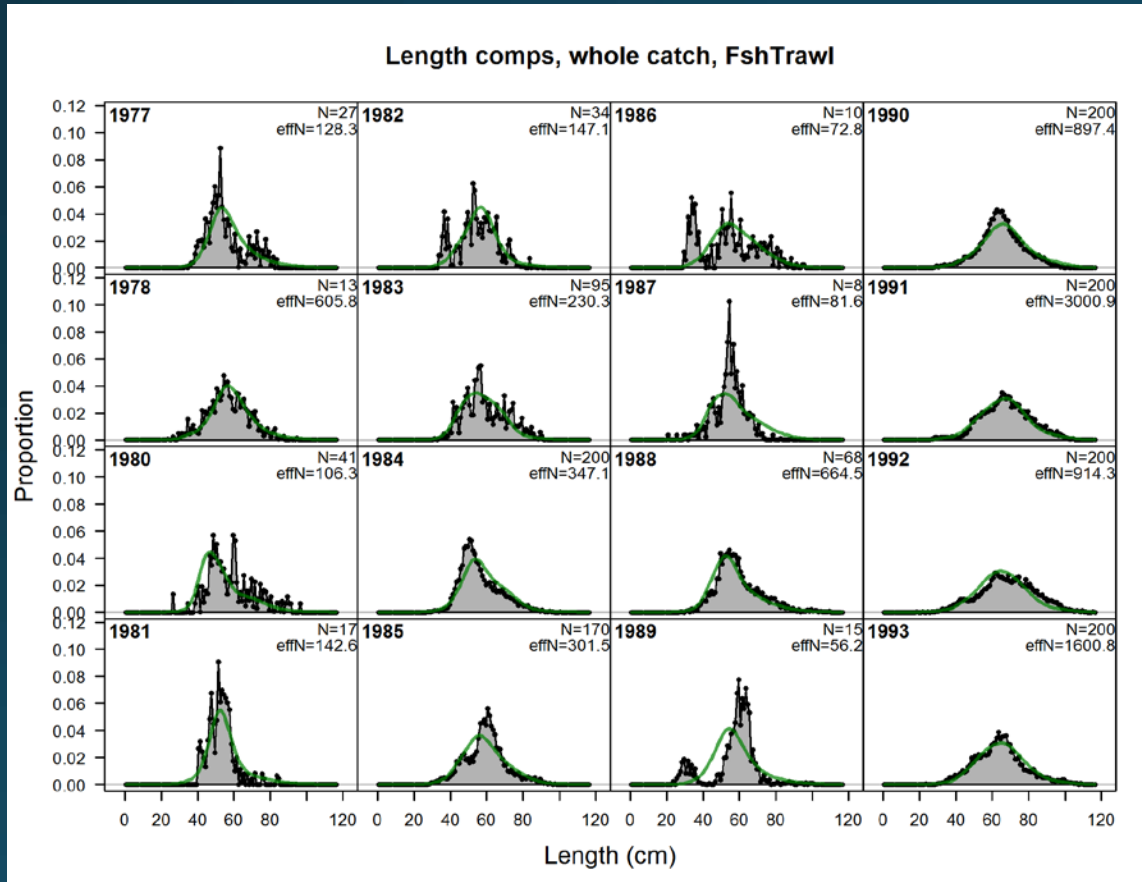


GOA Pacific cod

17.09.25 vs 17.09.26



- Model 17.09.25

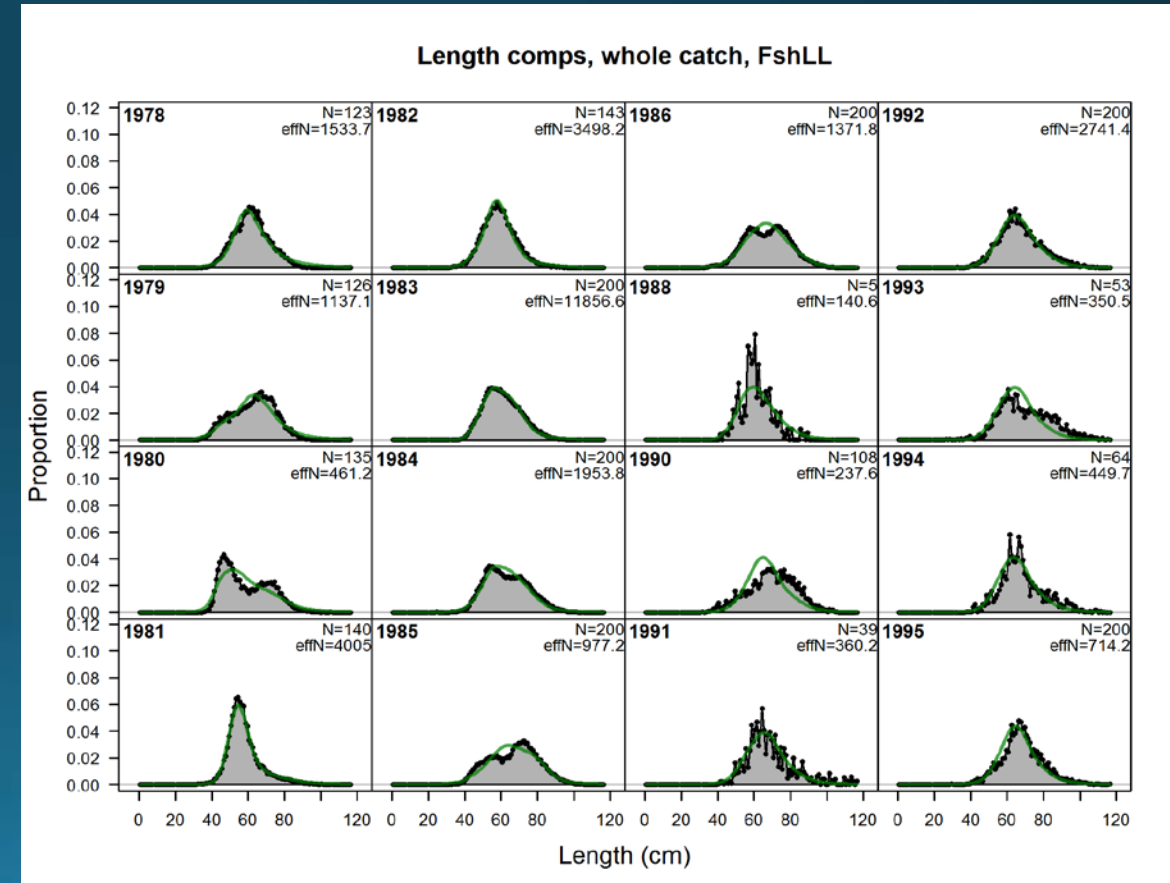
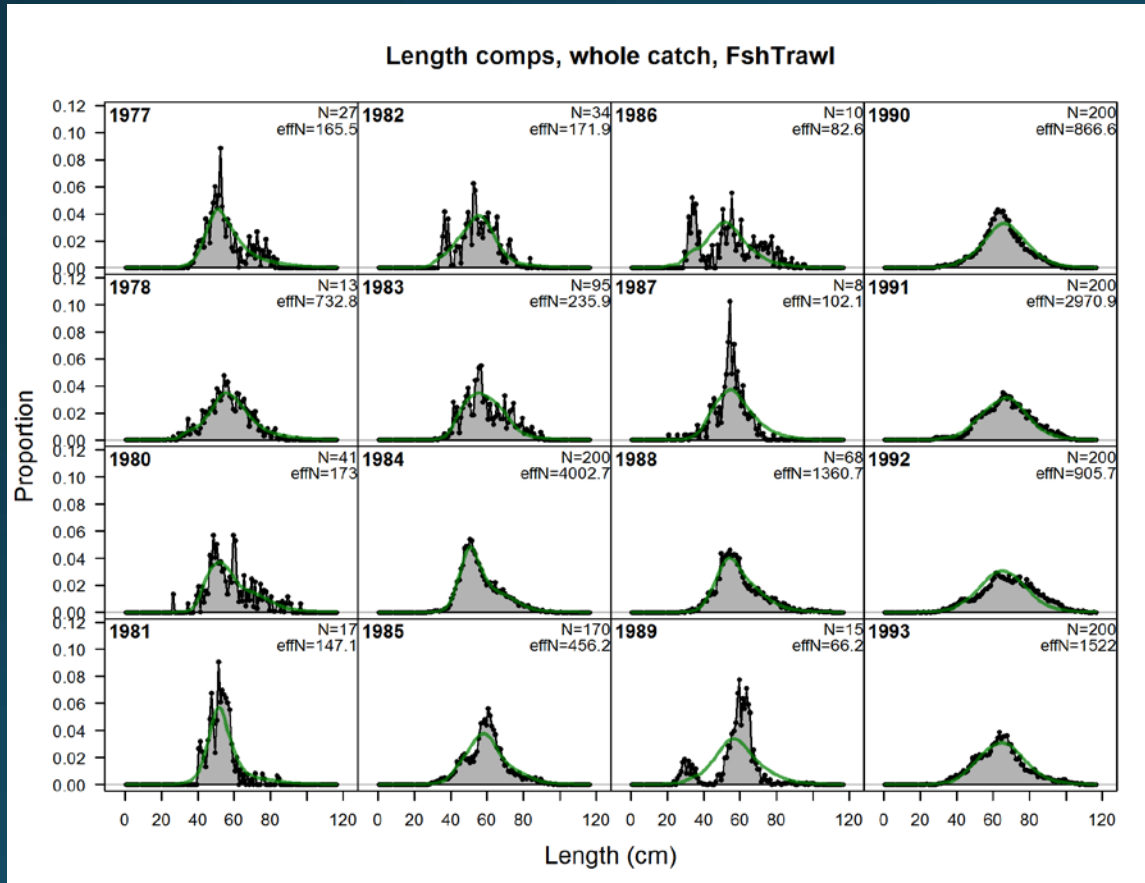


GOA Pacific cod

17.09.25 vs 17.09.26



- Model 17.09.26

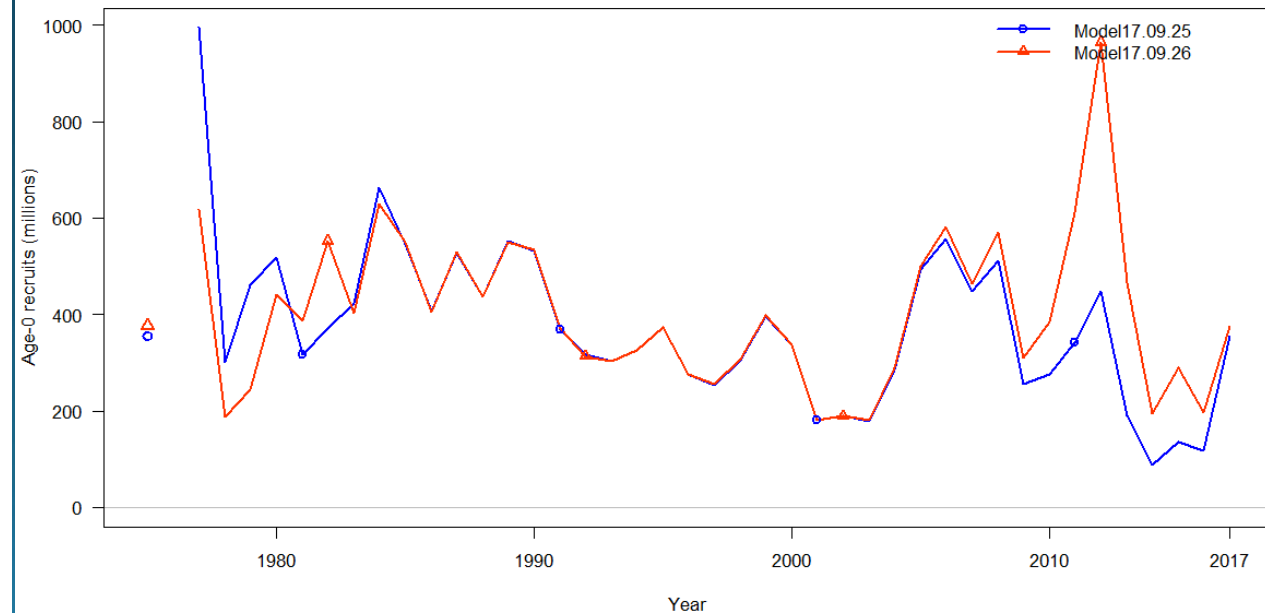
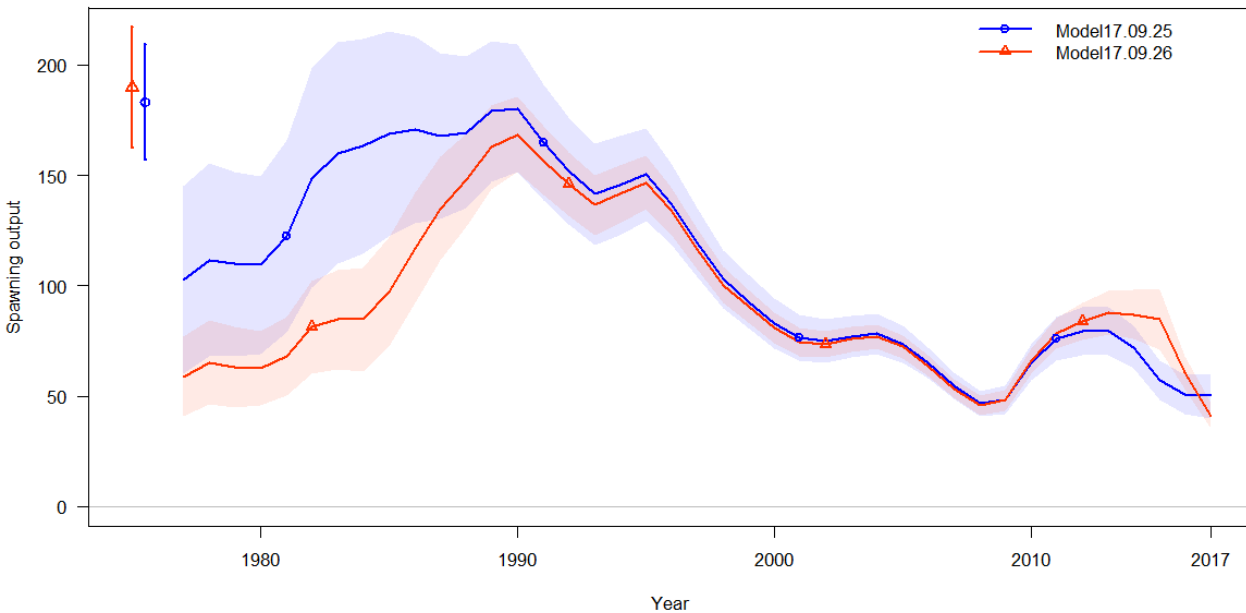


GOA Pacific cod

17.09.25 vs 17.09.26 Results



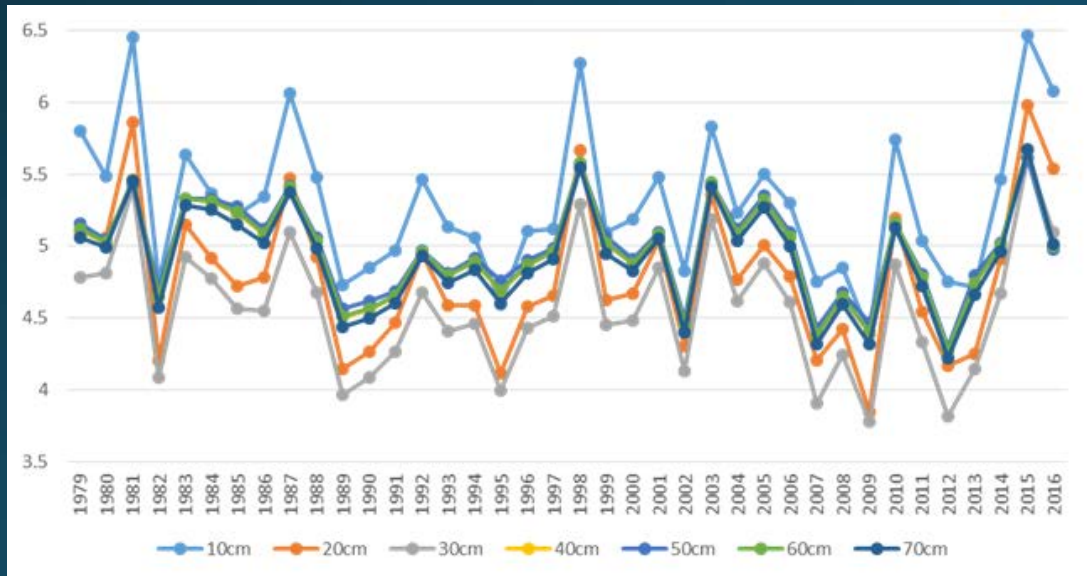
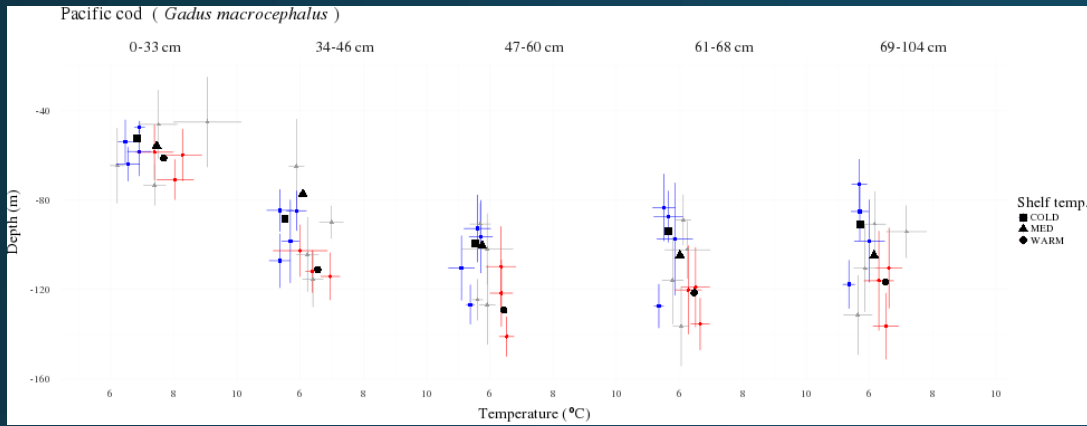
- Lower initial recruitment in 1977-1980
- Lower 1977-1996 spawning biomass
- Retains large 2011-2012 recruitment
- Build up, then sharp drop in biomass post-2015



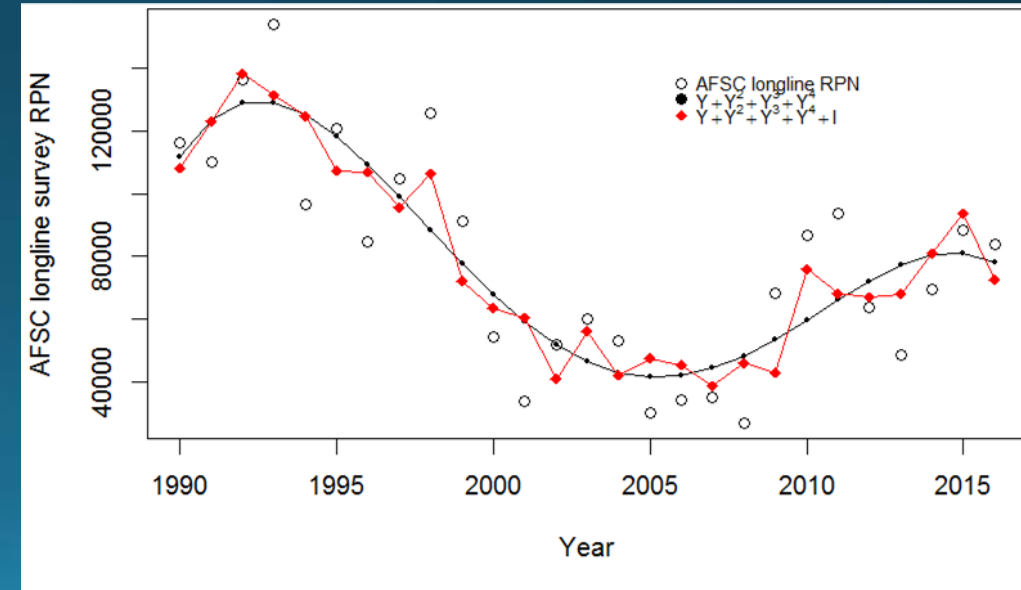
GOA Pacific cod Longline survey catchability



- Fit with 10 cm CFSR temperature index



Model	AIC	Δ_{AIC}	I_i	w_i	Evidence Ratio
$x=Y$	636.5	23.65	7.32E-06	0.000001	182,167.54
$x=Y+Y^2$	623.65	10.8	0.0045	0.000565	295.21
$x=Y+Y^2+Y^3$	622.78	9.93	0.0070	0.001163	143.31
$x=Y+Y^2+Y^3+Y^4$	617.32	4.47	0.1070	0.017832	9.35
$x=Y+Y^2+Y^3+Y^4+Y^5$	619.31	6.46	0.0396	0.006593	25.28
$x=Y+Y^2+Y^3+Y^4+I$	613.75	0.90	0.6376	0.106271	1.57
$x=Y+Y^2+Y^3+Y^4+I^2$	612.85	0	1.0000	0.166667	1.00
$x=Y+Y^2+Y^3+Y^4+I^2+I^3$	613.30	0.45	0.8004	0.133406	1.25

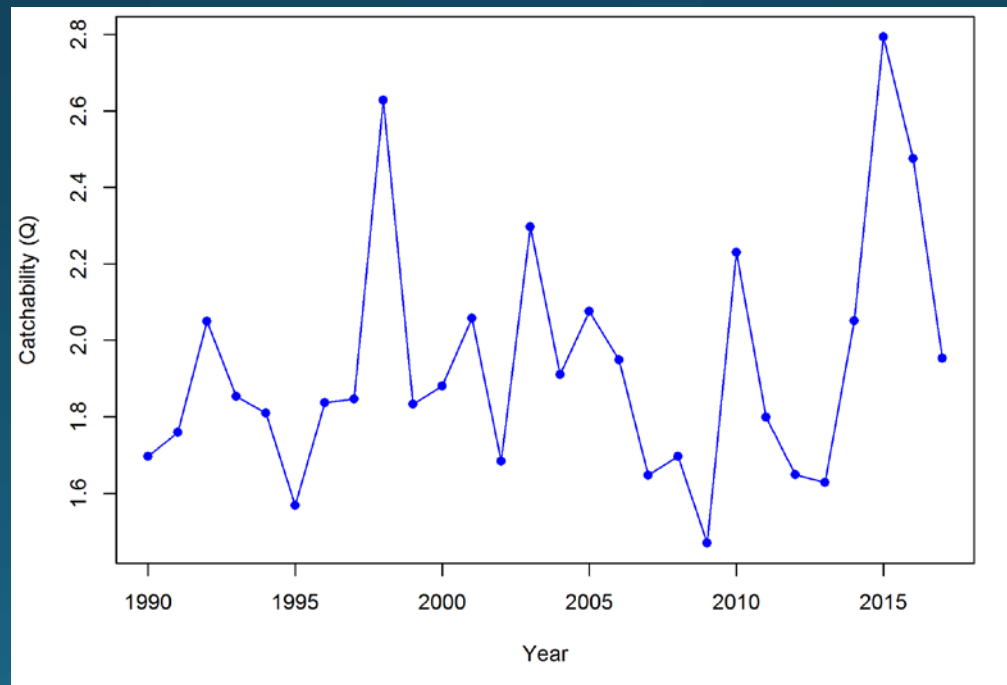


GOA Pacific cod

17.09.26 vs 17.09.31



- Fit AFSC longline survey with 10 cm CFSR temp. index
- Reduced natural mortality prior σ to 0.1 for both blocks
 - $M_{\text{standard}} = 0.48$, $M_{2015-2016} = 0.69$



GOA Pacific cod

17.09.26 vs 17.09.31



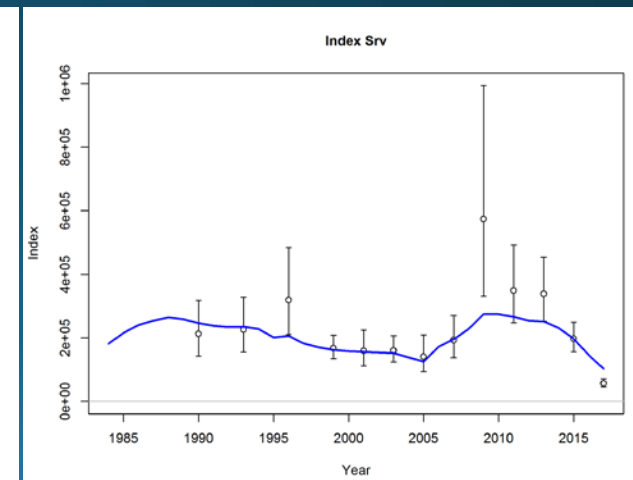
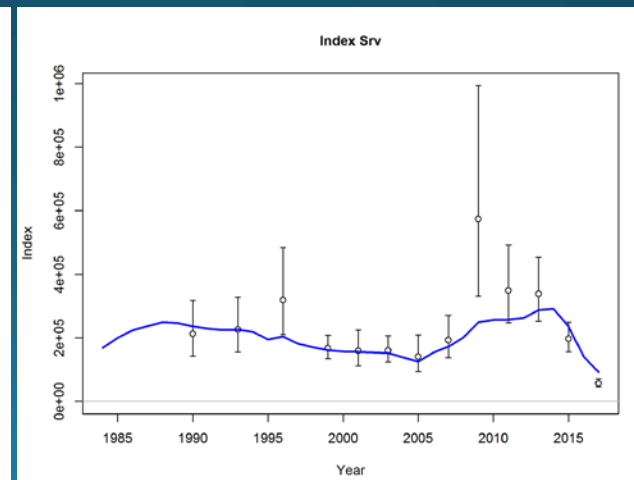
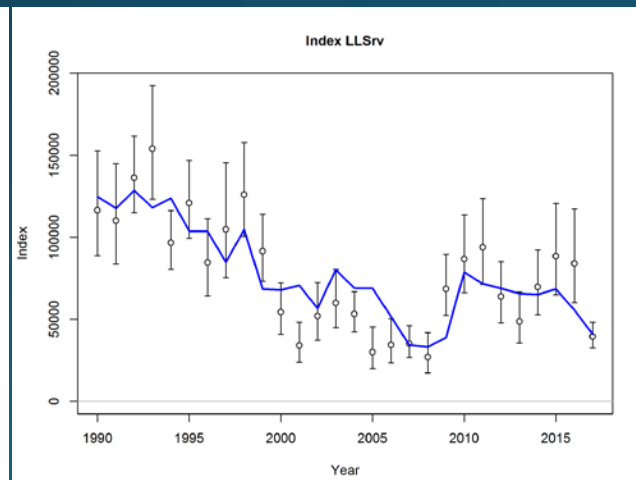
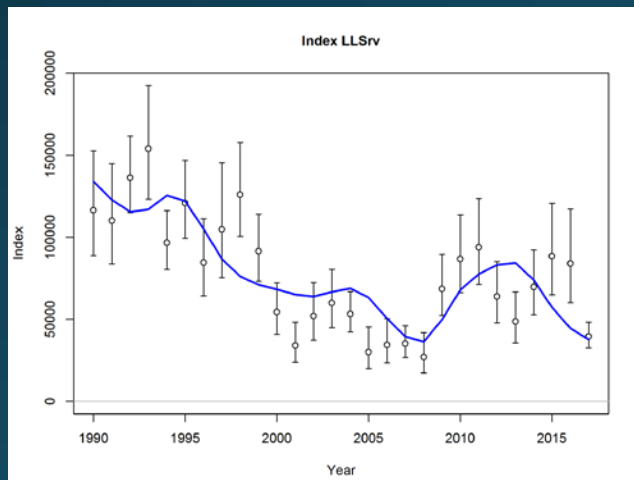
- Improves AIC by 24.22 overall
 - Improved fit to AFSC longline survey (11.52 to 0.61 LL)
 - Slightly degraded fit to AFSC trawl survey (-5.54 to -0.85 LL)

Model 17.09.26

Model 17.09.31

Model 17.09.26

Model 17.09.31

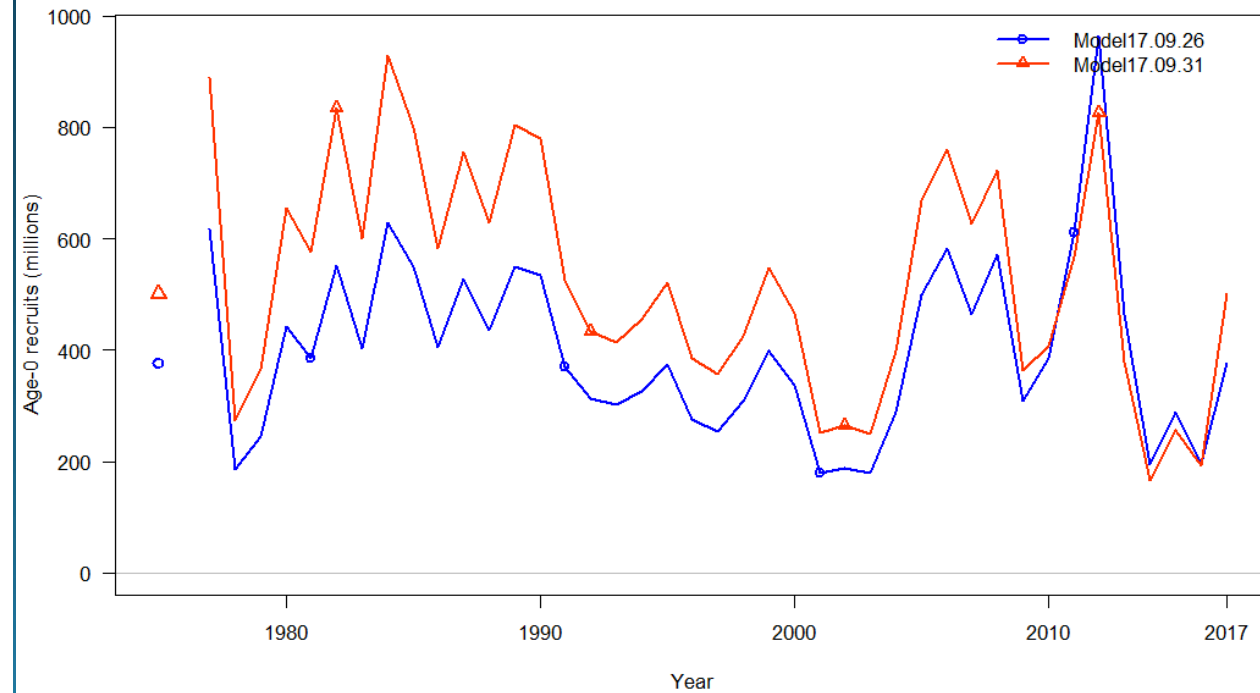
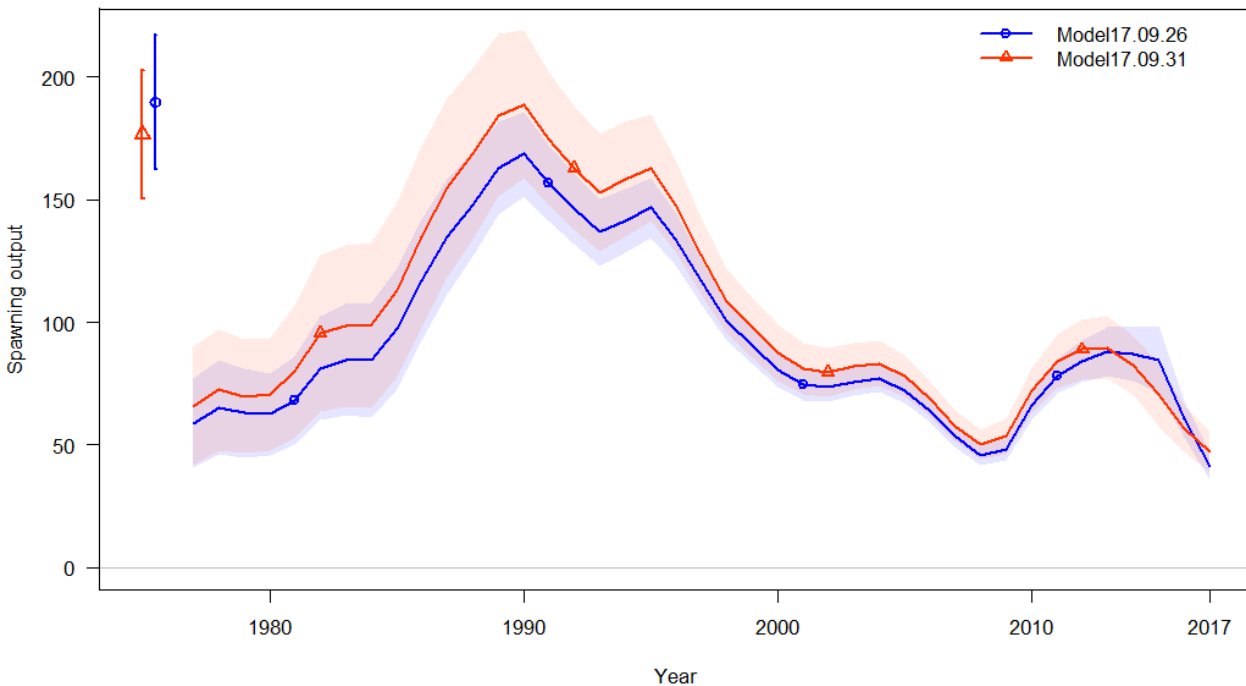


GOA Pacific cod

17.09.26 vs 17.09.31



- Higher M_{standard} results in higher overall recruitment and biomass
- Lower $M_{2015-2016}$ results in less steep decline and relatively lower 2011-2012 recruitment

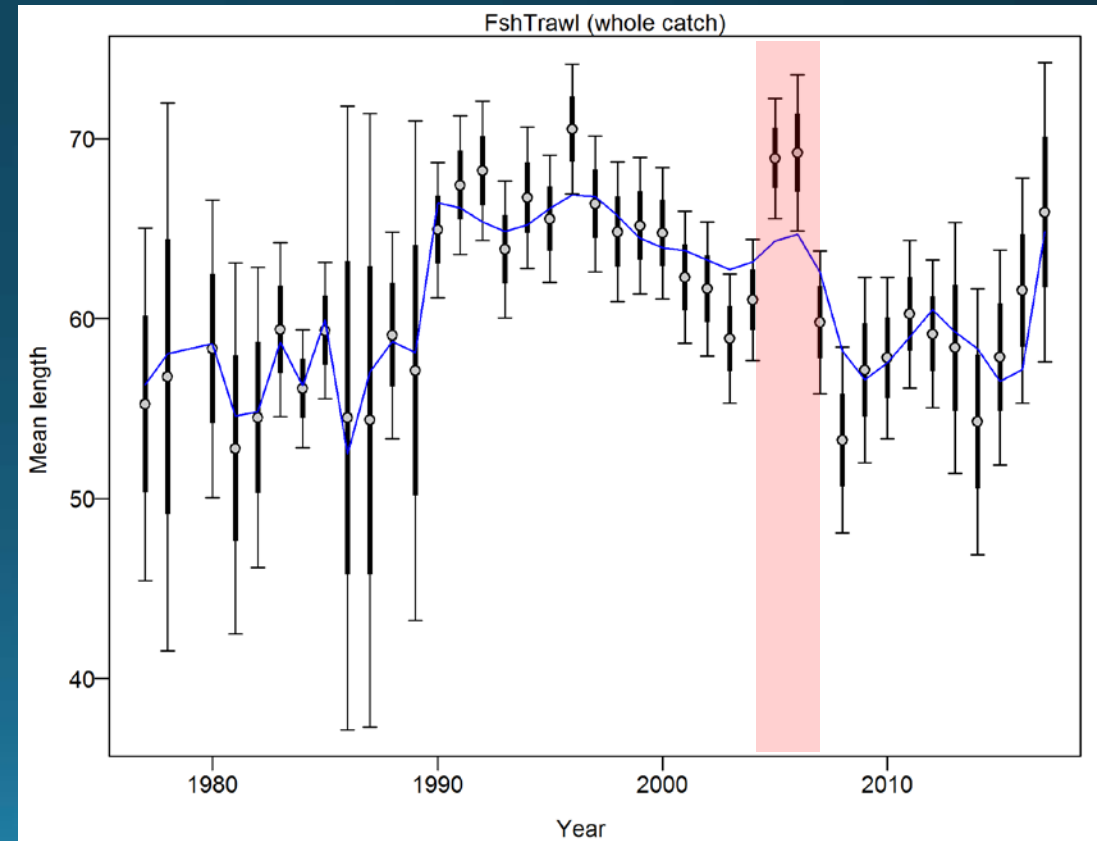
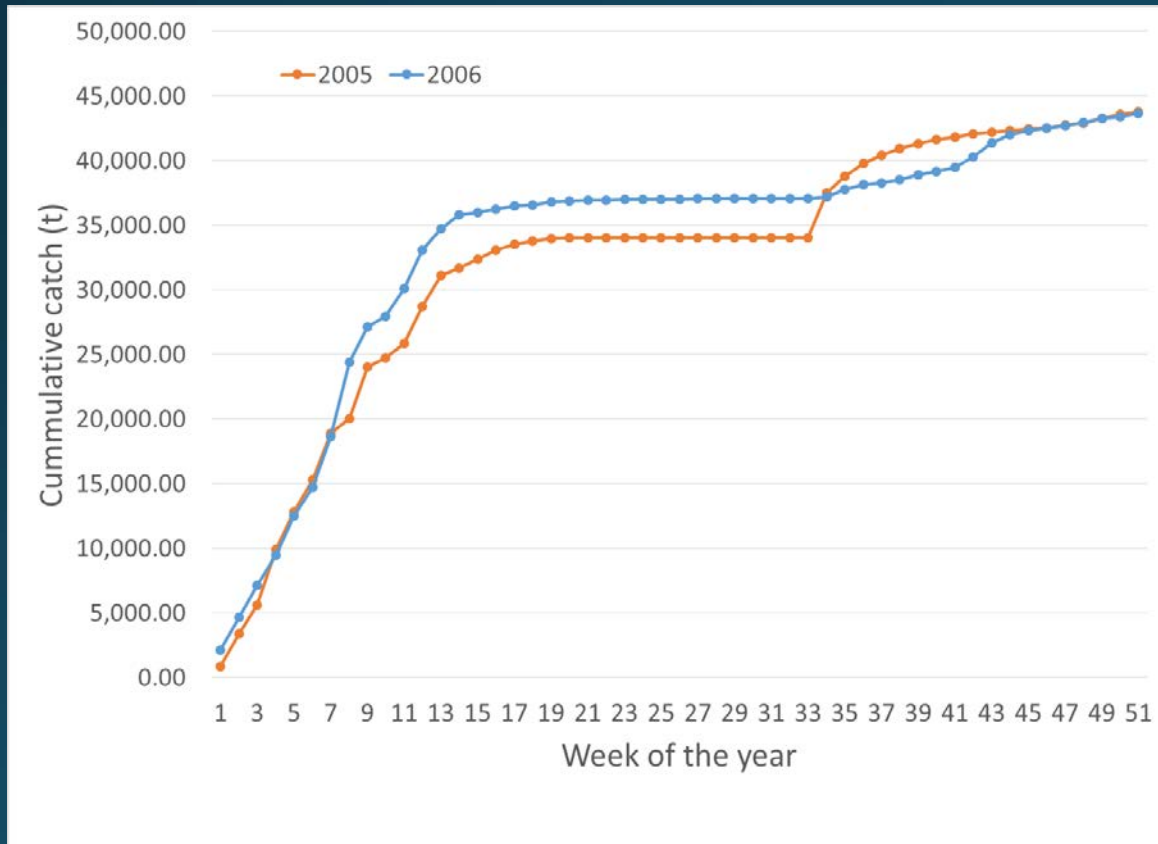


GOA Pacific cod

New trawl and longline fishery selectivity block 2005-2006



- A-season only trawl fishery resulted in landing larger fish for 2005-2006



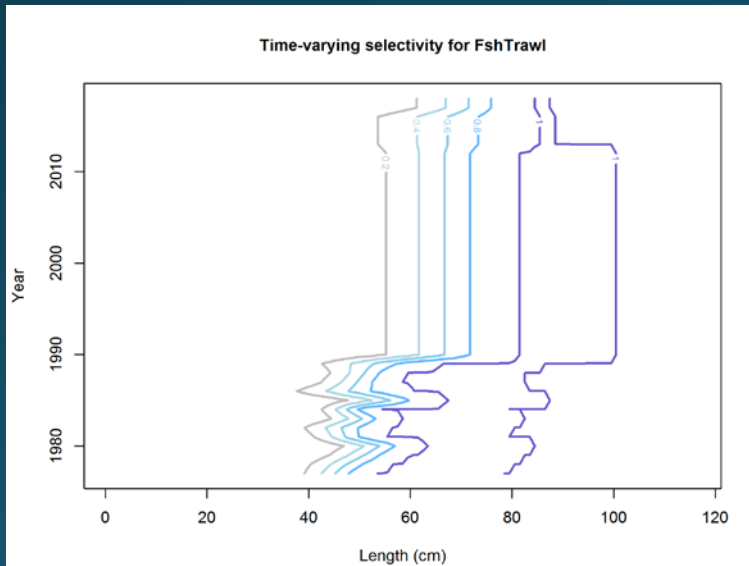
GOA Pacific cod

17.09.31 vs 17.09.35

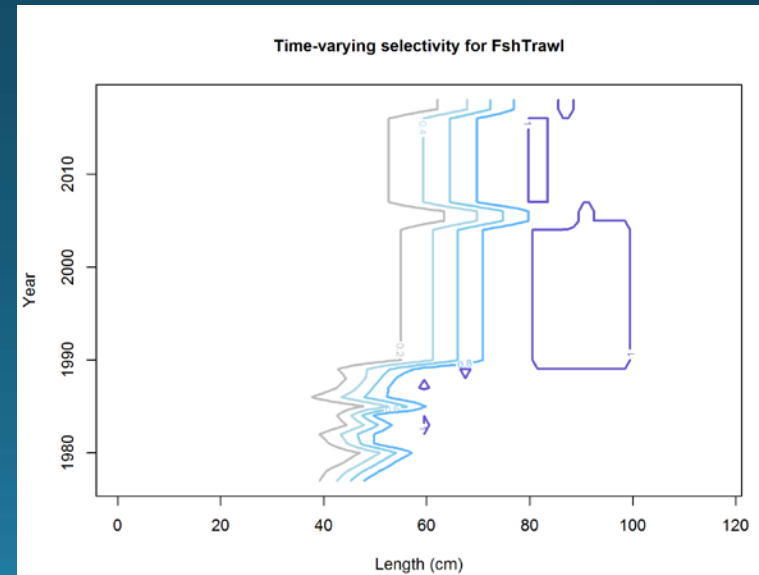


- Additional time block for trawl and longline fishery selectivity for 2005-2006
- Improves model fit AIC -57.9
 - Improved fits to the trawl length and age composition data

Model17.09.31



Model17.09.35

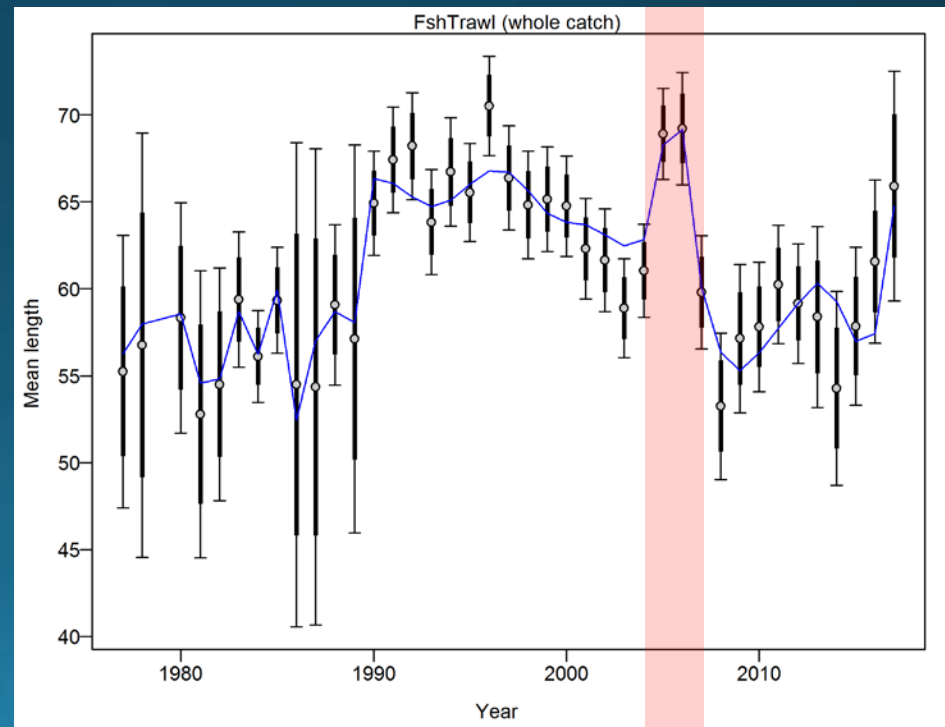
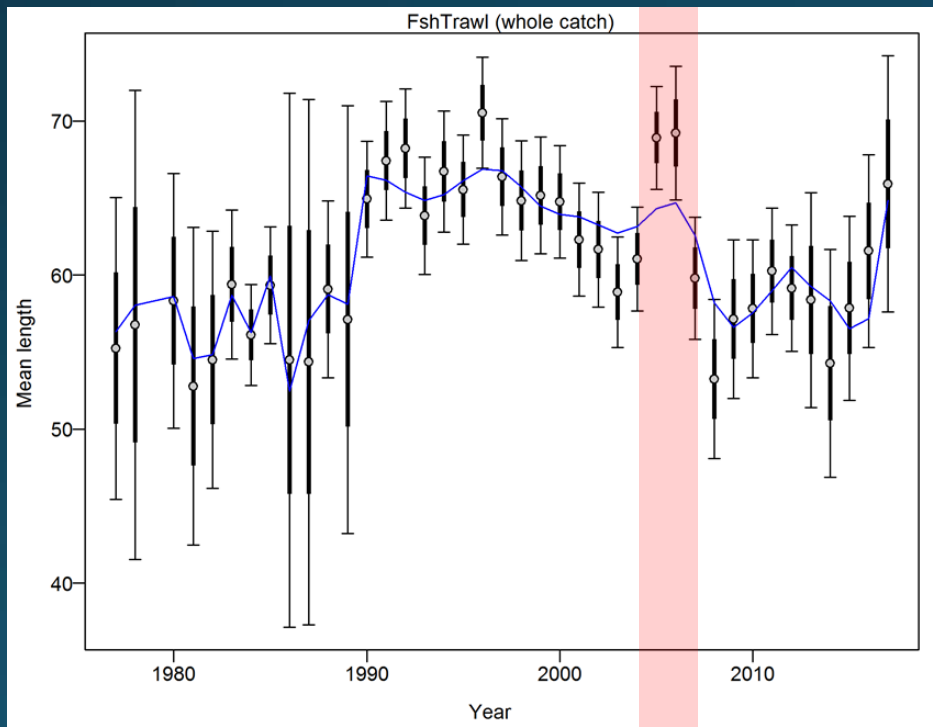


GOA Pacific cod

17.09.31 vs 17.09.35



- Additional time block for trawl and longline fishery for 2005-2006
- Improves model fit AIC -57.9
 - All improvement to the trawl and longline length composition data fit

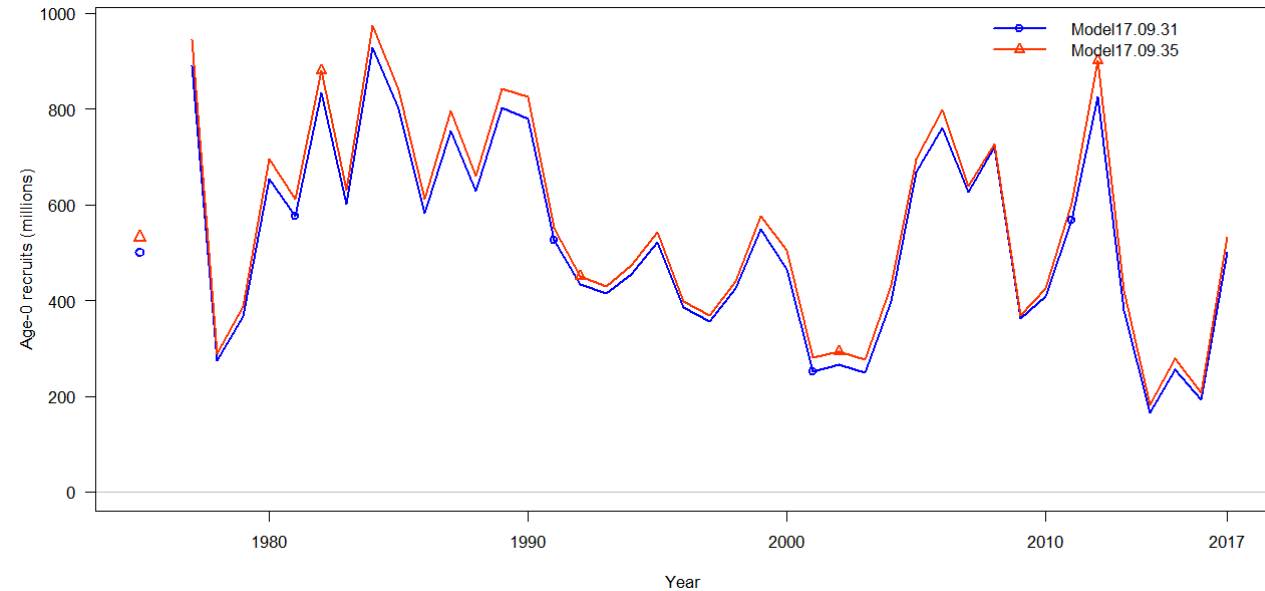
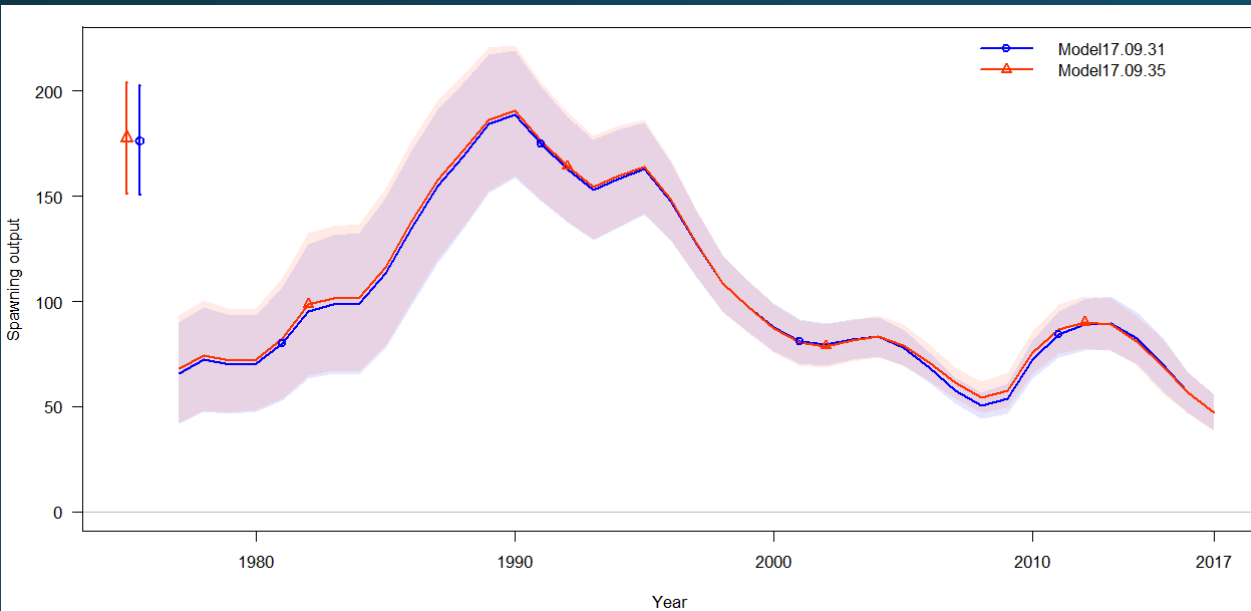


GOA Pacific cod

17.09.31 vs 17.09.35



- M small increase
 - $M_{\text{standard}} = 0.49$, $M_{2015-2016} = 0.71$
- Trawl survey catchability decreased
 - Q_{trawl} from 1.48 to 1.47



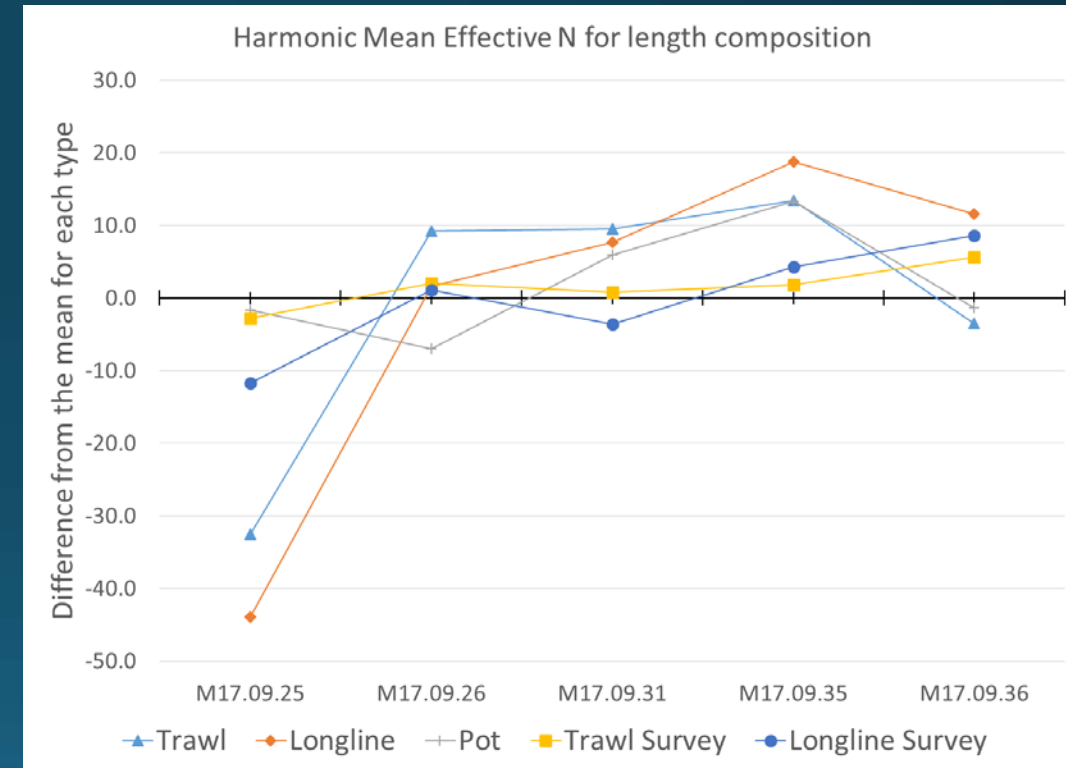
GOA Pacific cod

Francis T.A18 weighting

17.09.35 vs 17.09.36



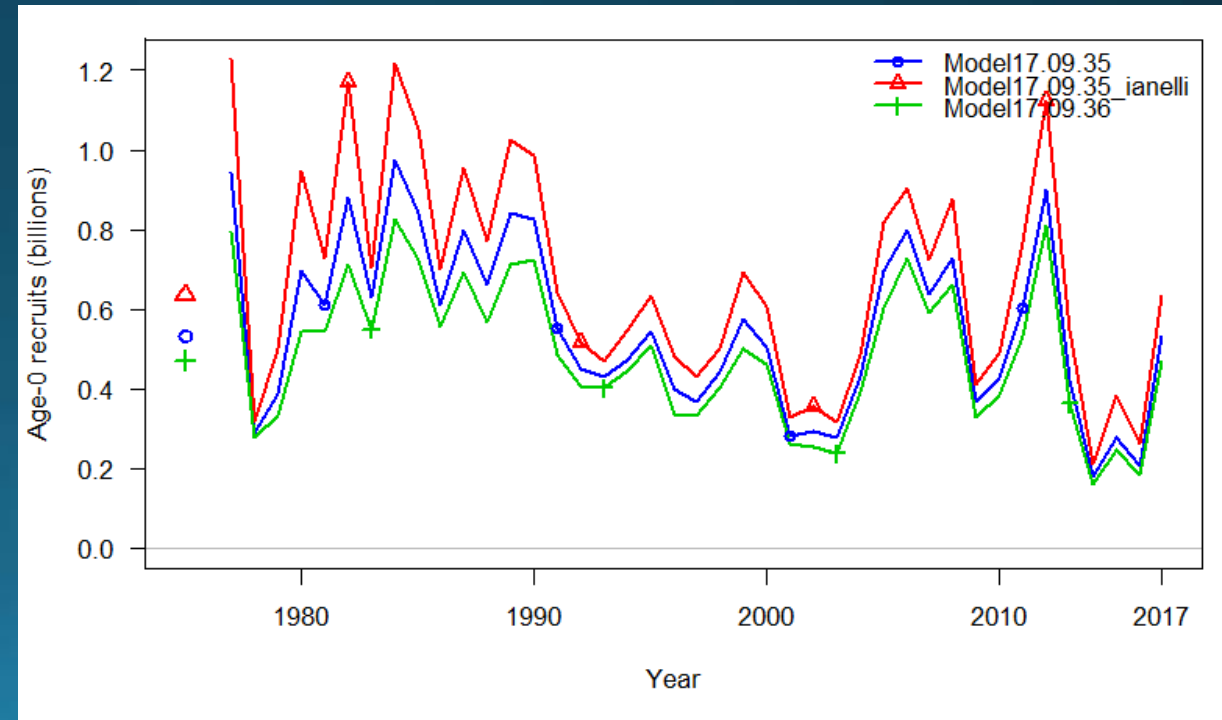
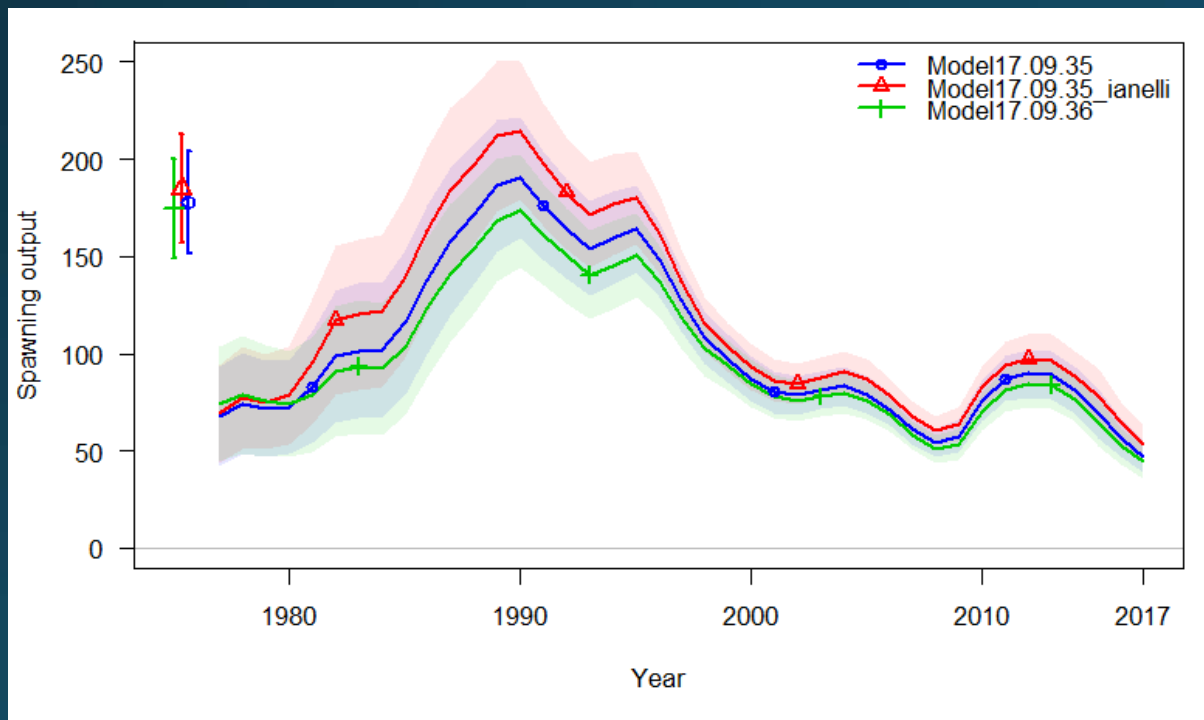
- Francis weighting suggests lower weight on fishery length composition
- Not comparable through AIC or total likelihoods however,
 - Marginal improved fit to AFSC survey length composition (\downarrow LL and \uparrow Effn)
 - Marginal improvement to AFSC trawl index ($\downarrow < 1$ LL)
 - Worse fit to AFSC longline survey ($\uparrow < 3$ LL)
 - Worse fit to fishery composition (small \downarrow EffN for all fisheries)



GOA Pacific cod Model selection - Tuning



- Results for Model 17.09.35 between Francis tuning (Model 17.09.36) and McAlister and Ianelli tuning methods.

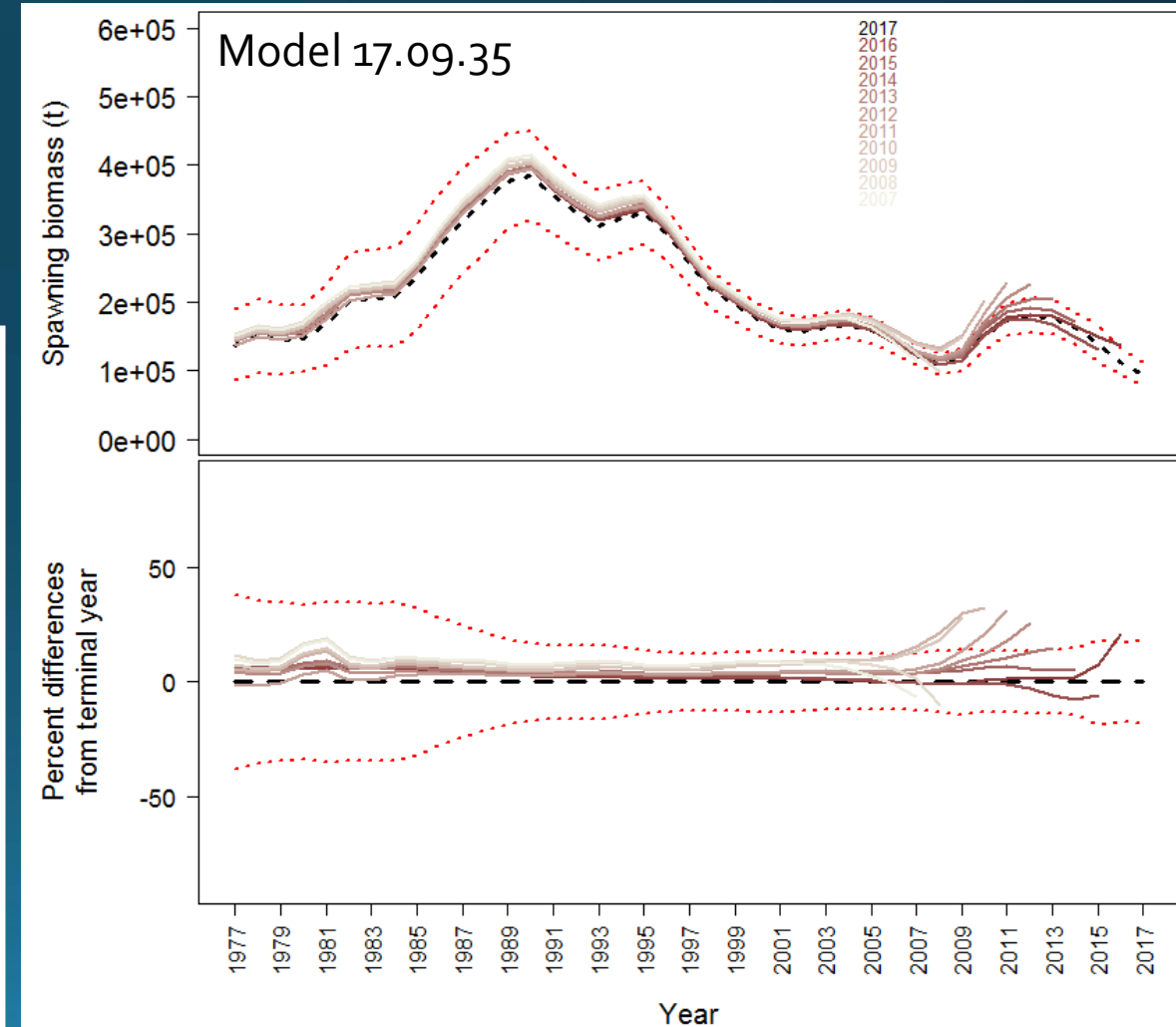
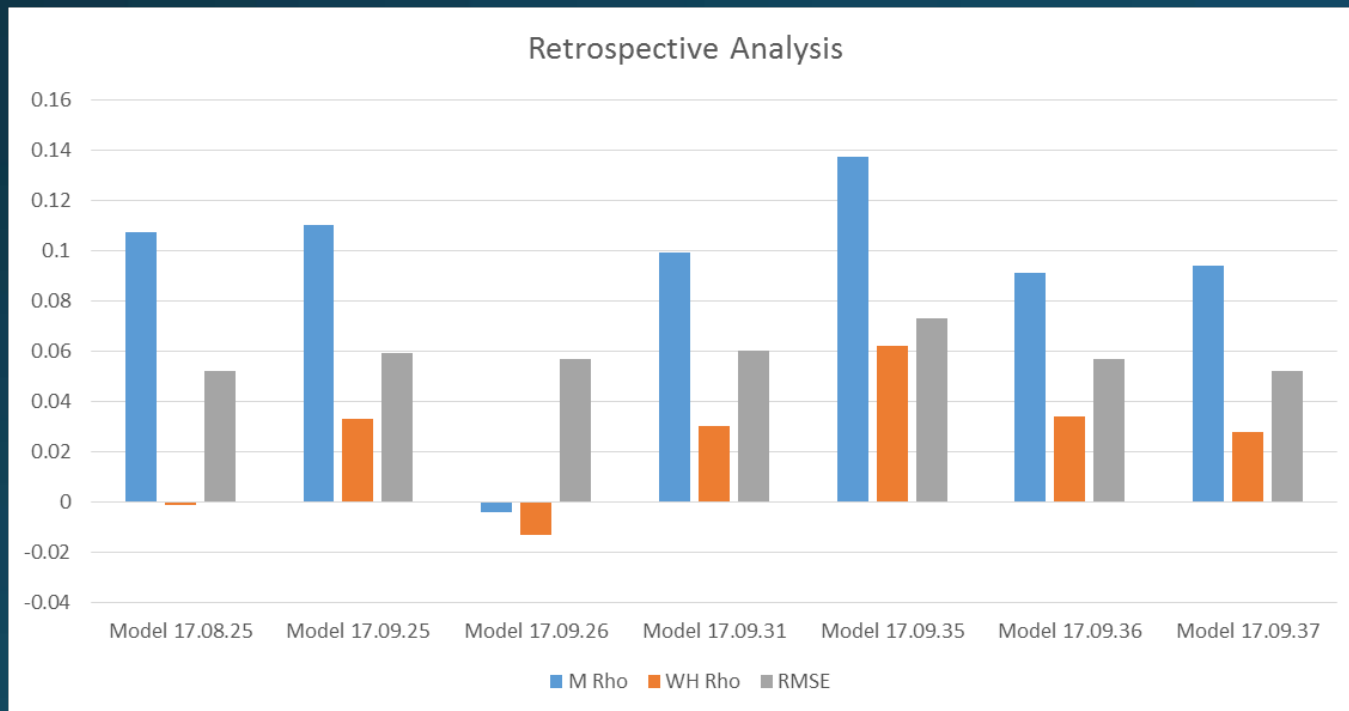


GOA Pacific cod

Model selection - Retrospective analysis



- 10-year peal
- All model Mohn's Rho within acceptable bounds

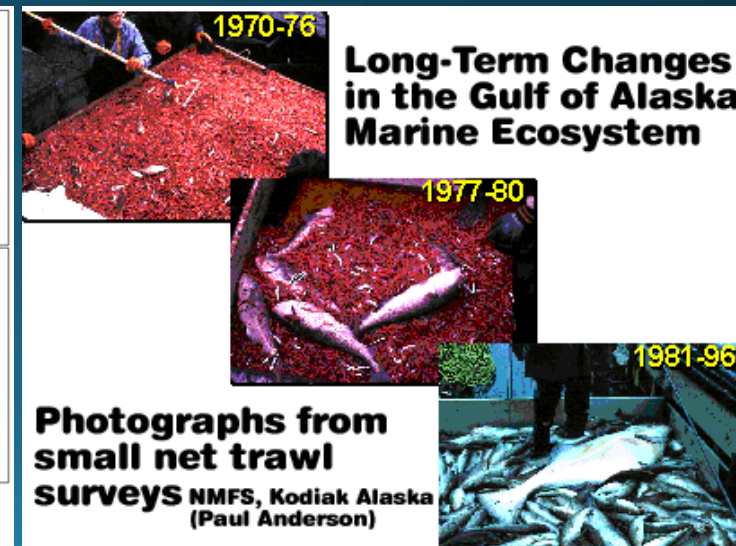
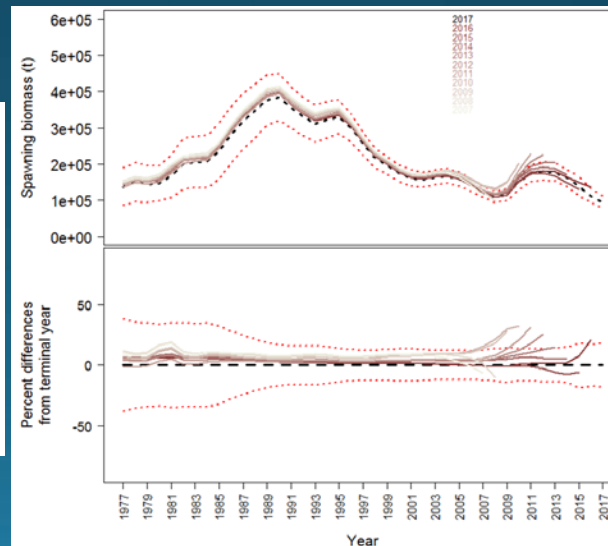
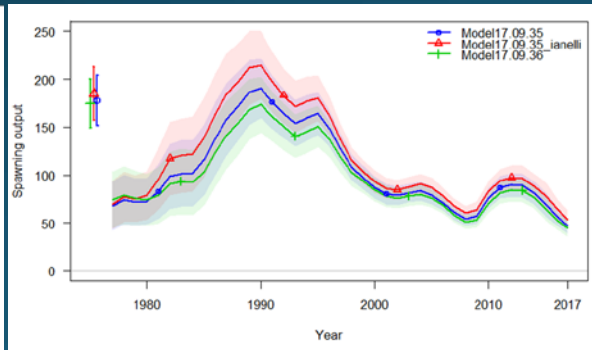
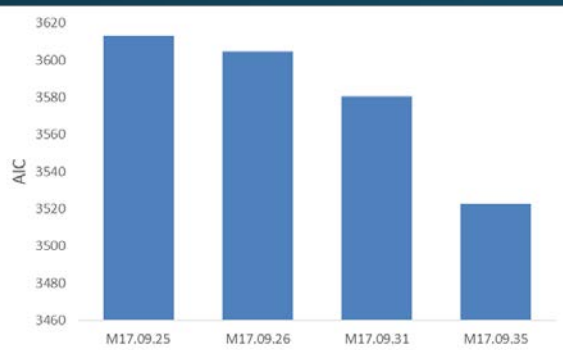


GOA Pacific cod

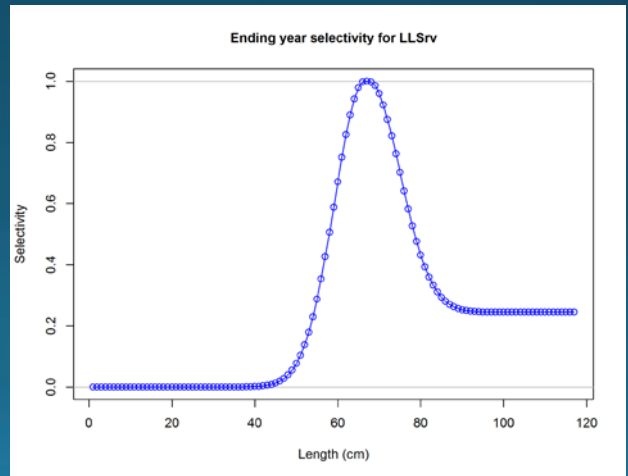
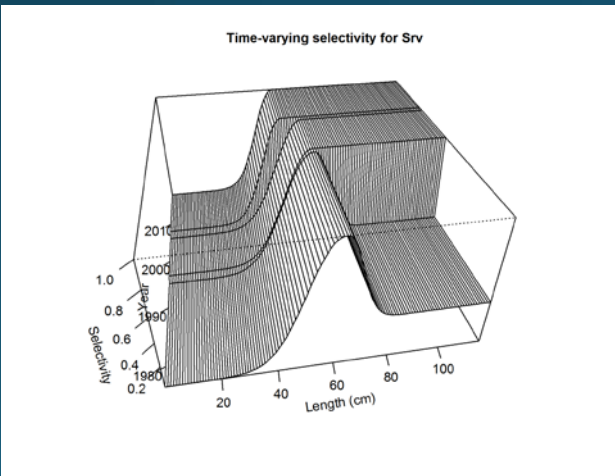
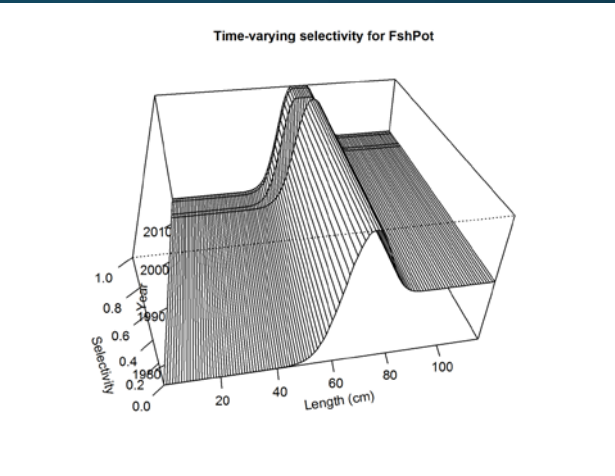
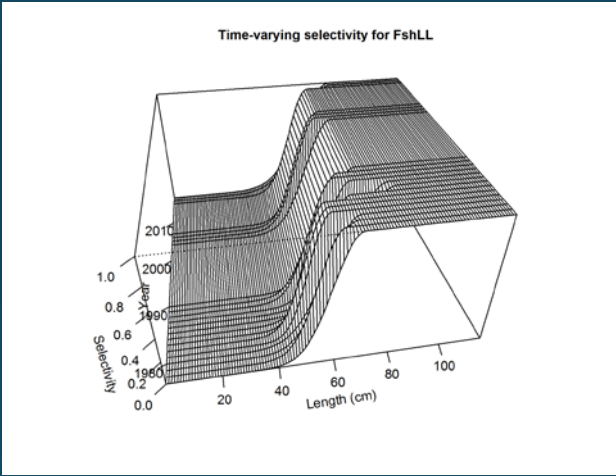
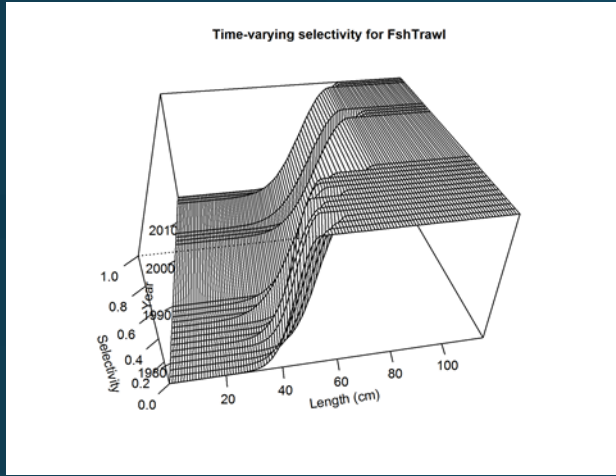
Model selection – Model17.09.35



- Of the comparable models Model17.09.35 has the lowest AIC
- Mid-way between Francis tuning and McAllister and Ianelli methods
- Acceptable retrospective pattern
- Biomass dynamics consistent with published history (Anderson and Piatt, 1999)



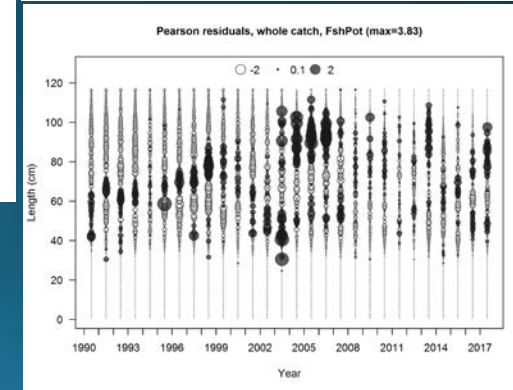
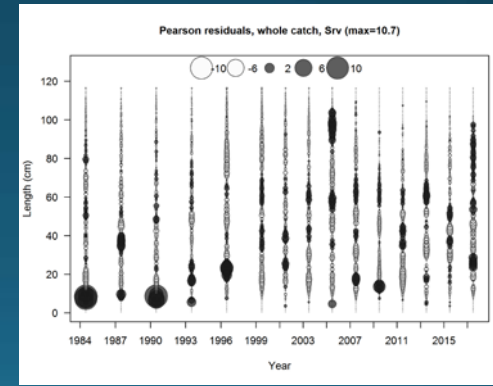
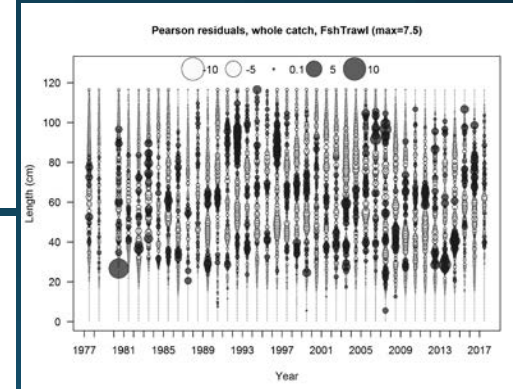
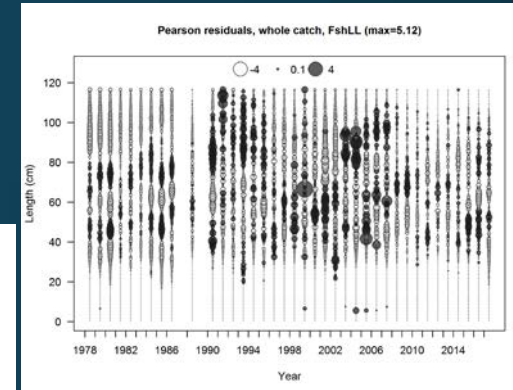
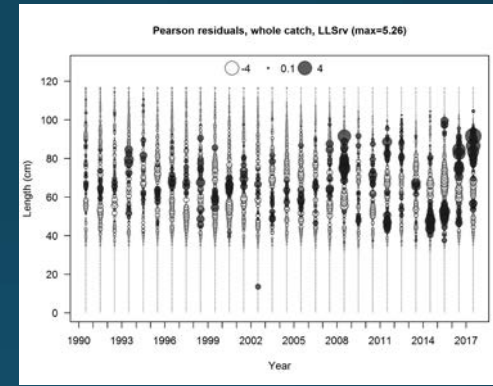
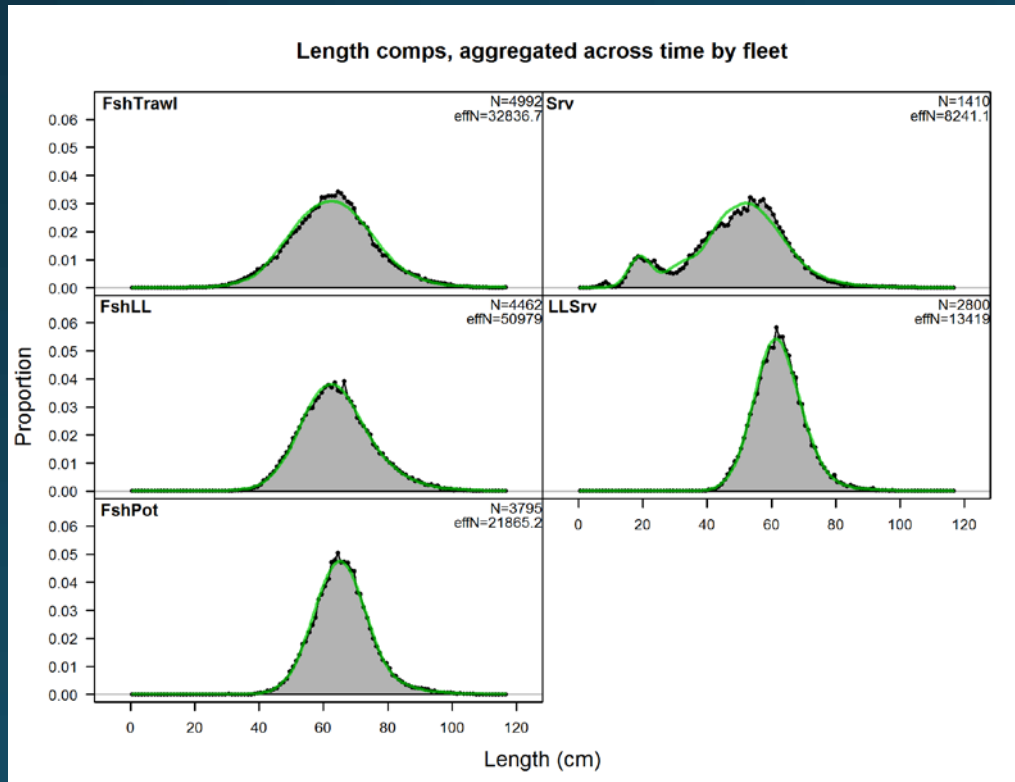
GOA Pacific cod Model 17.09.35 Selectivities



GOA Pacific cod Model 17.09.35 Composition fit

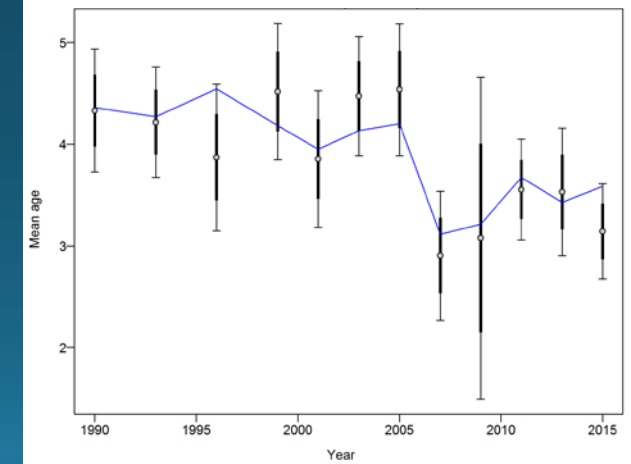
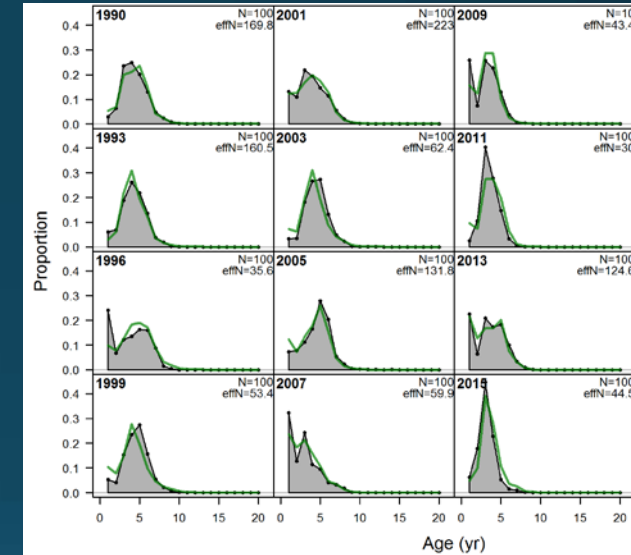
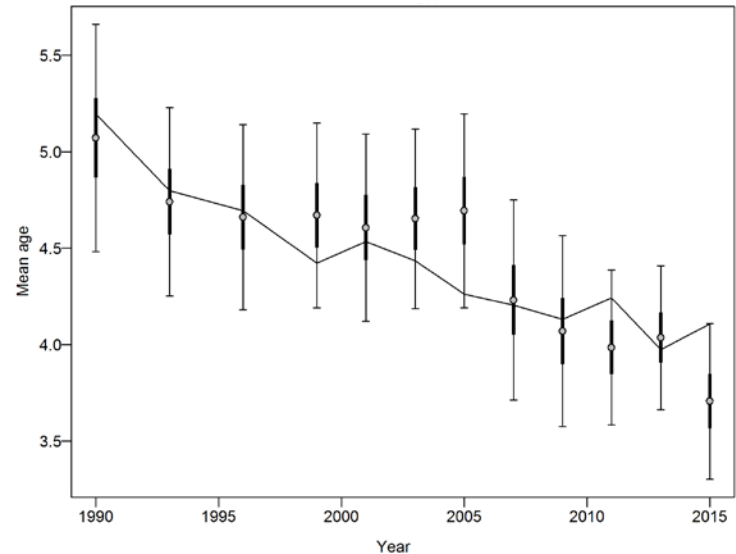
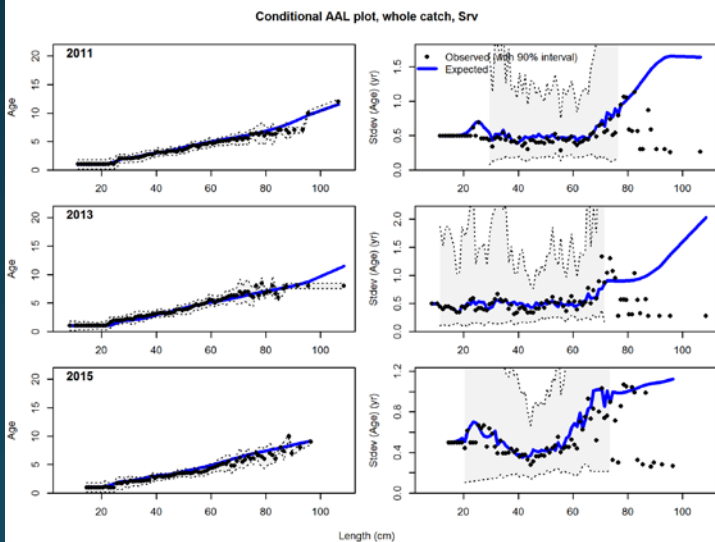
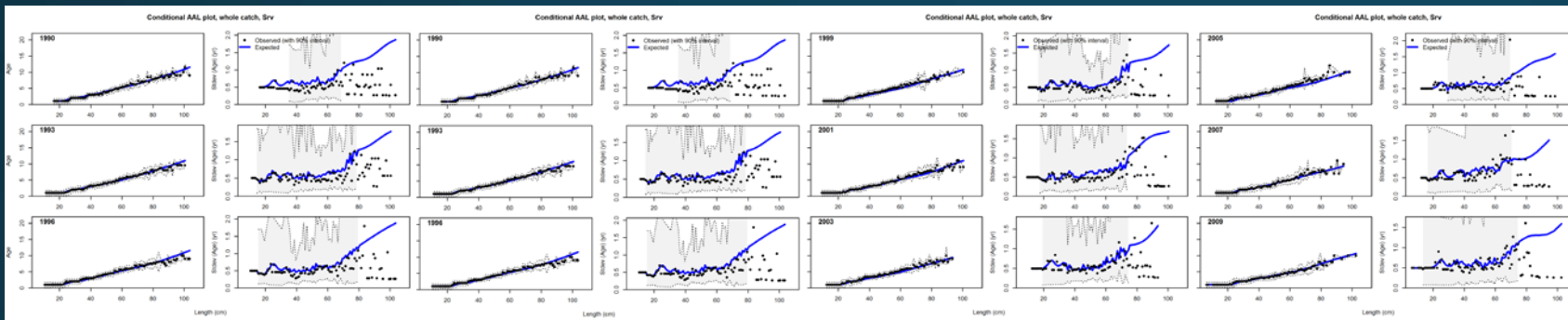


- Good fit to all components
- No substantial trend in residuals



GOA Pacific cod

Model 17.09.35 Age composition and conditional length at age

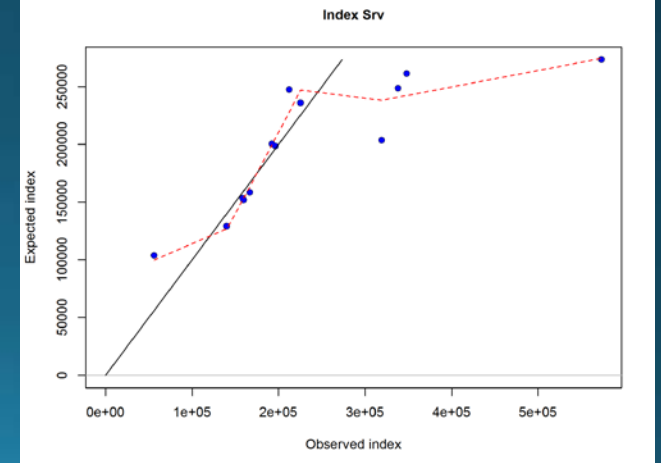
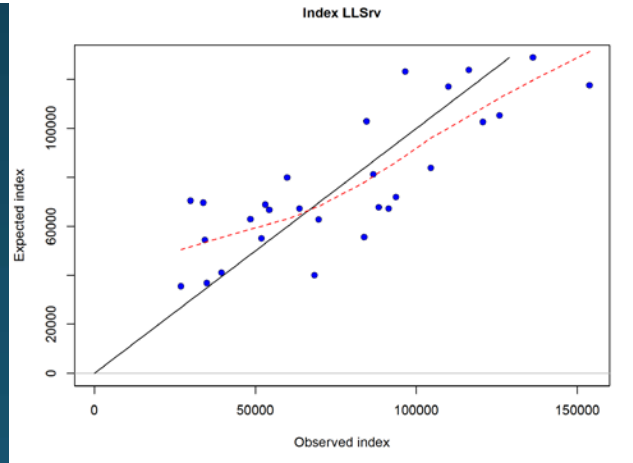
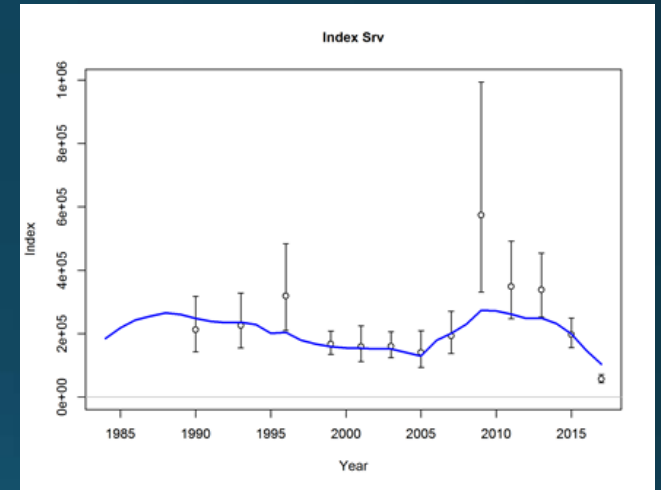
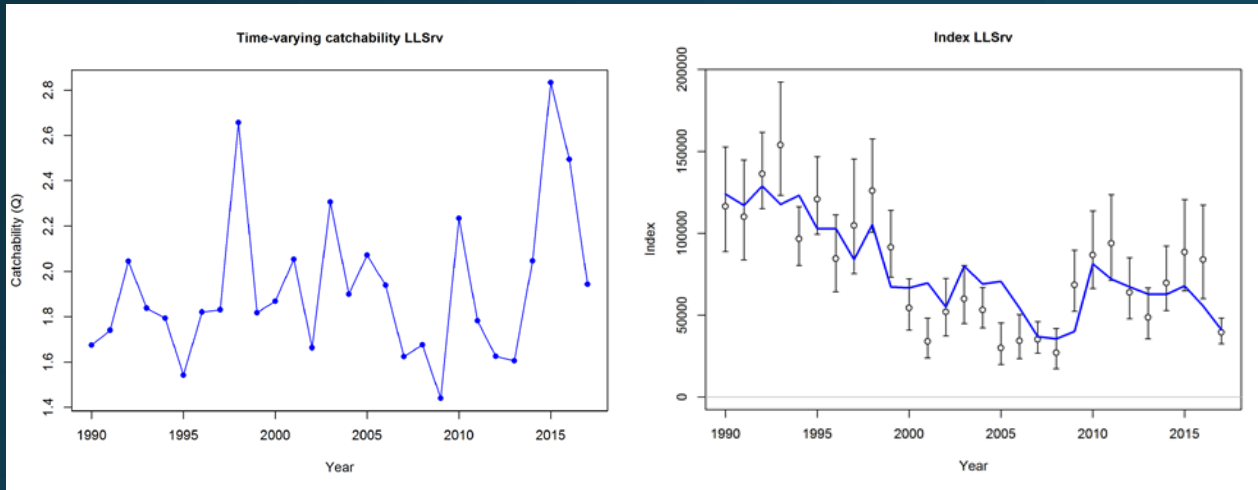


GOA Pacific cod Model 17.09.35 Index Fits



AFSC longline survey

AFSC trawl survey

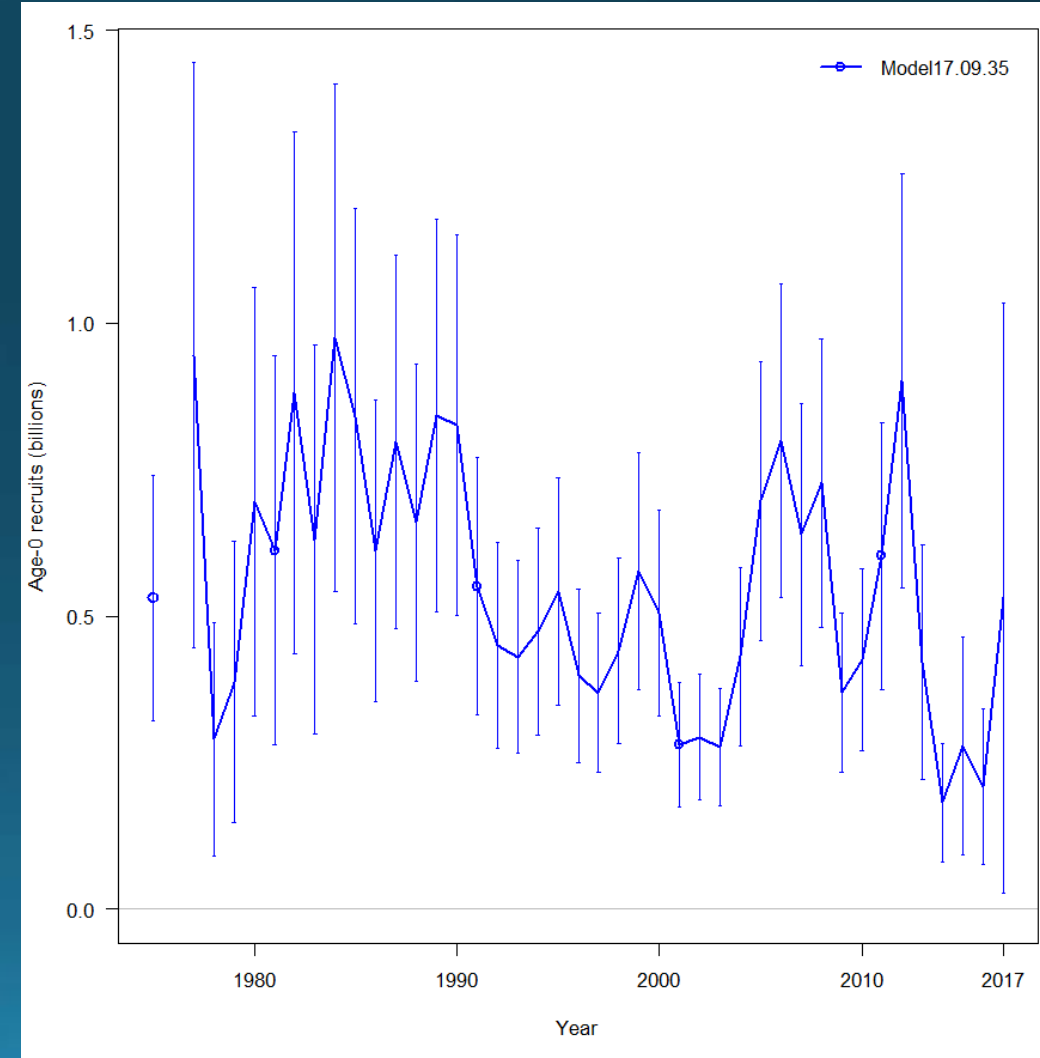


GOA Pacific cod

Model 17.09.35 Recruitment



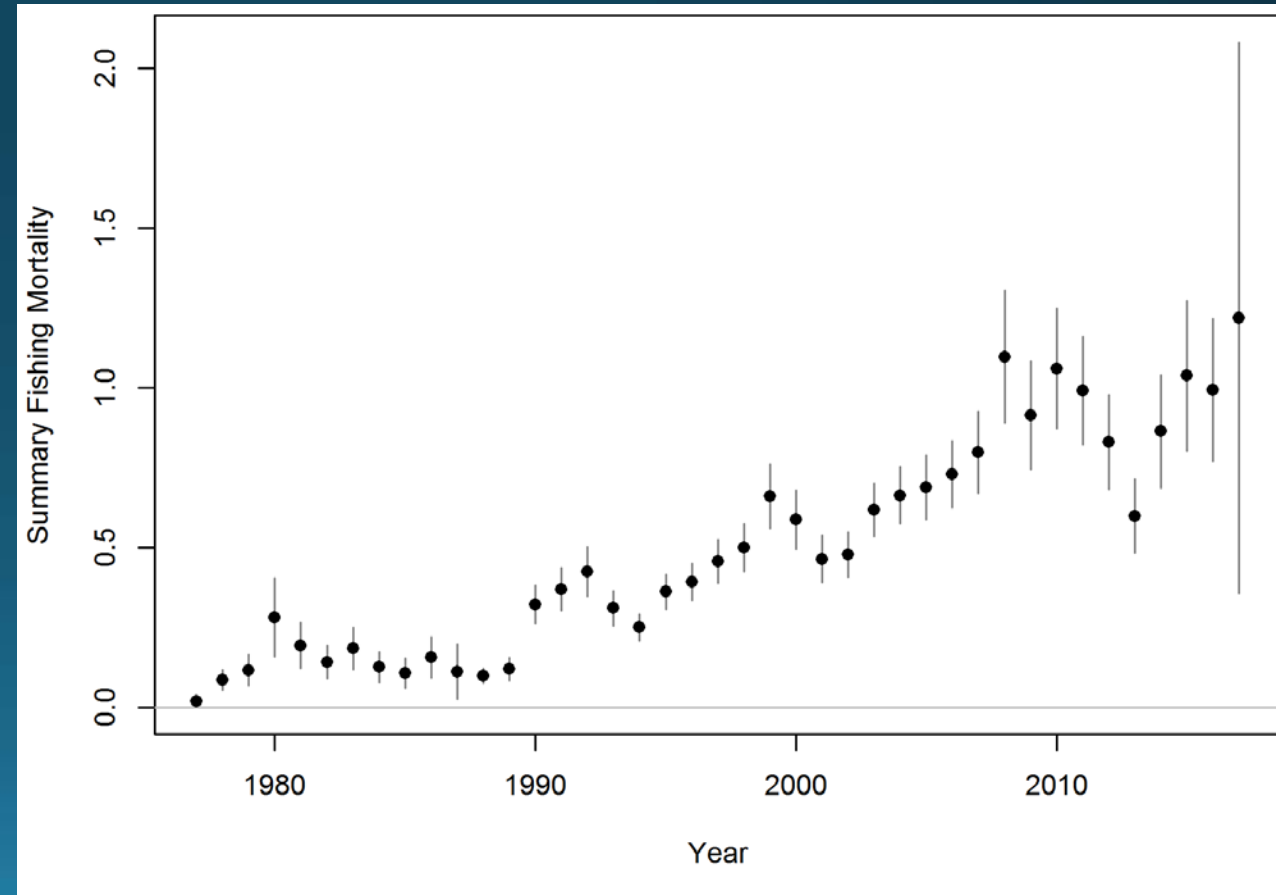
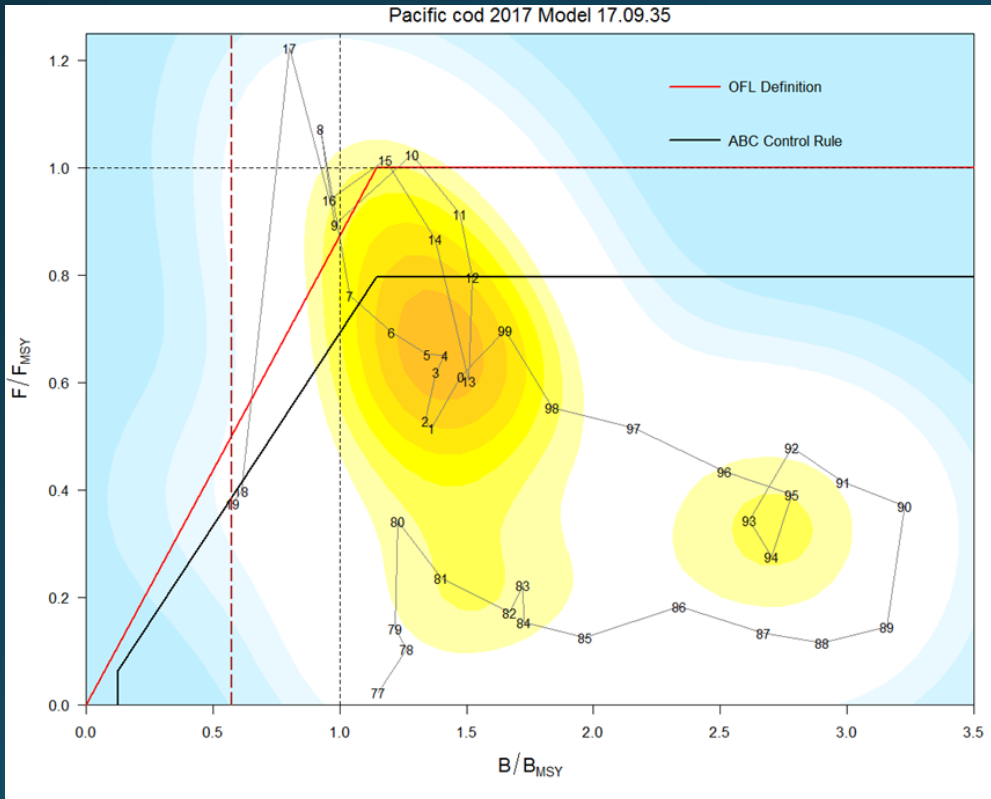
- Largest single recruitment was in 1984 with 0.98×10^9 fish
- 1980-1990 series of large recruitment events ($\mu = 0.76 \times 10^9$)
- 1991-2004 series of poor recruitment $\mu = 0.43 \times 10^9$
- 2012 recruits at 0.90×10^9
- 2014 lowest recruitment estimate in time series at 0.14×10^9
- 2016 and 2015 second and third lowest recruitment estimates



GOA Pacific cod Model 17.09.35 Fishing mortality



- Relatively high F
 - 2008-2010 and 2015-2017

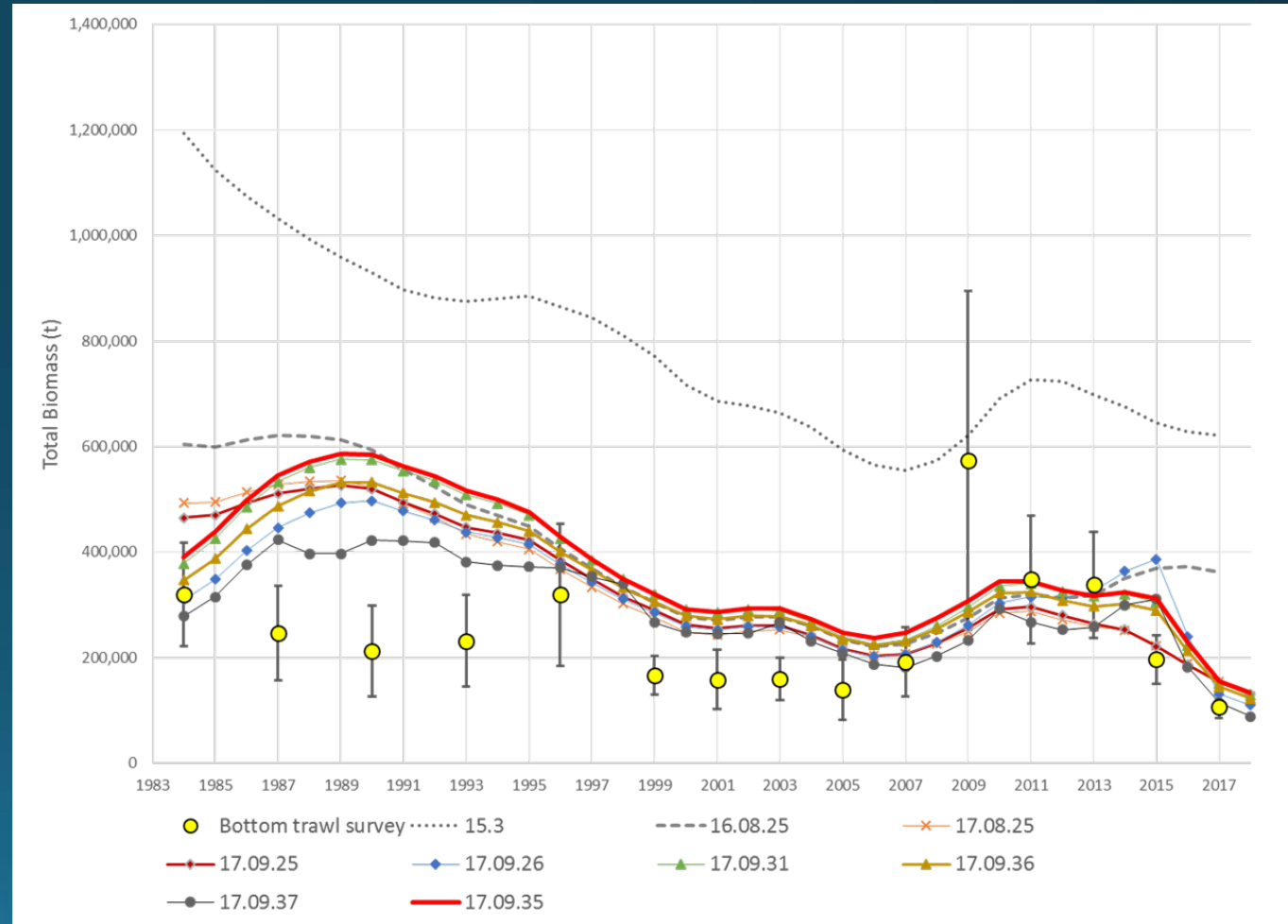


GOA Pacific cod

Model 17.09.35 Total biomass



- Effective catchability for 1996 to 2017 = 0.71
- Gadoid outburst peaked in late 1989 (585,807 t)
- 2018 is an all-time low for the time series (132,723 t)
- Previous low in 2006 (237,068 t)

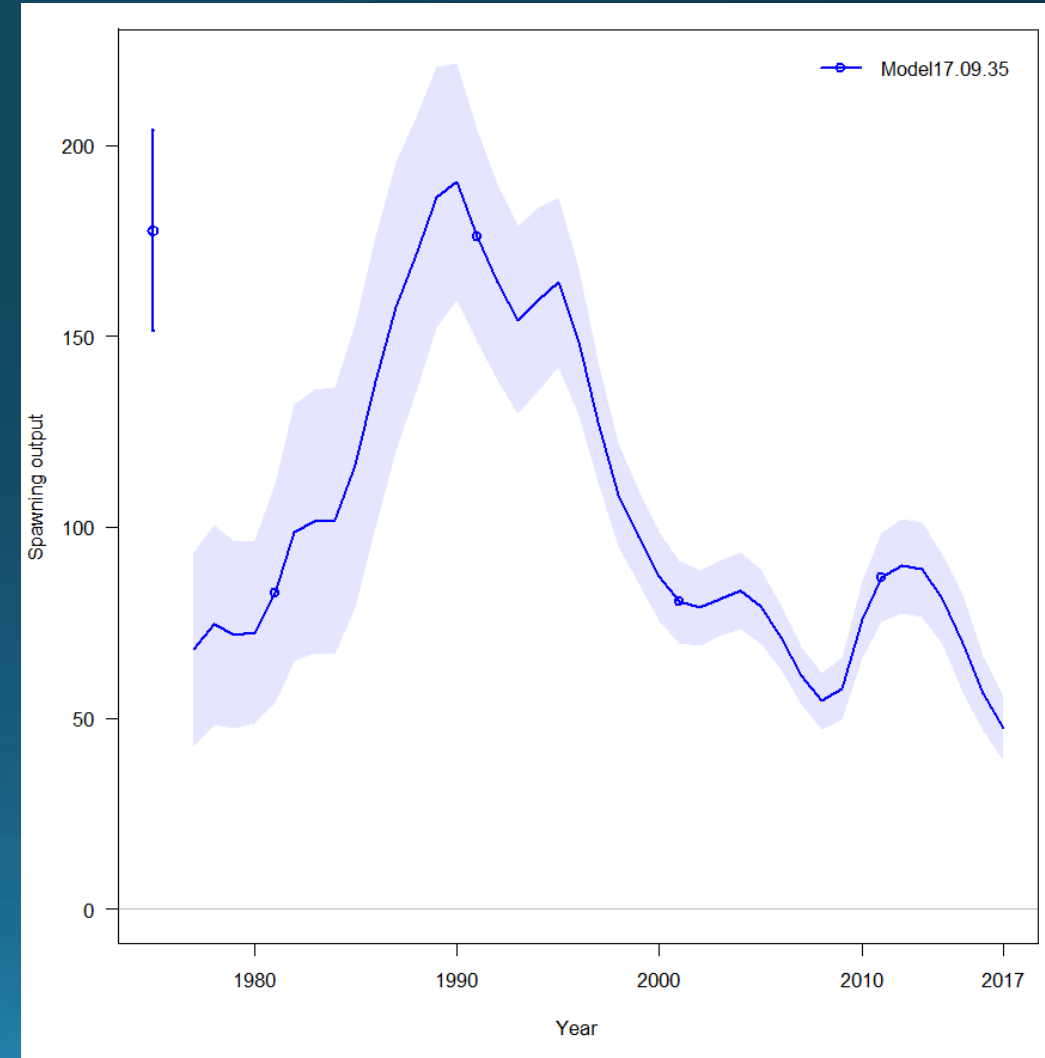


GOA Pacific cod

Model 17.09.35 Spawning biomass



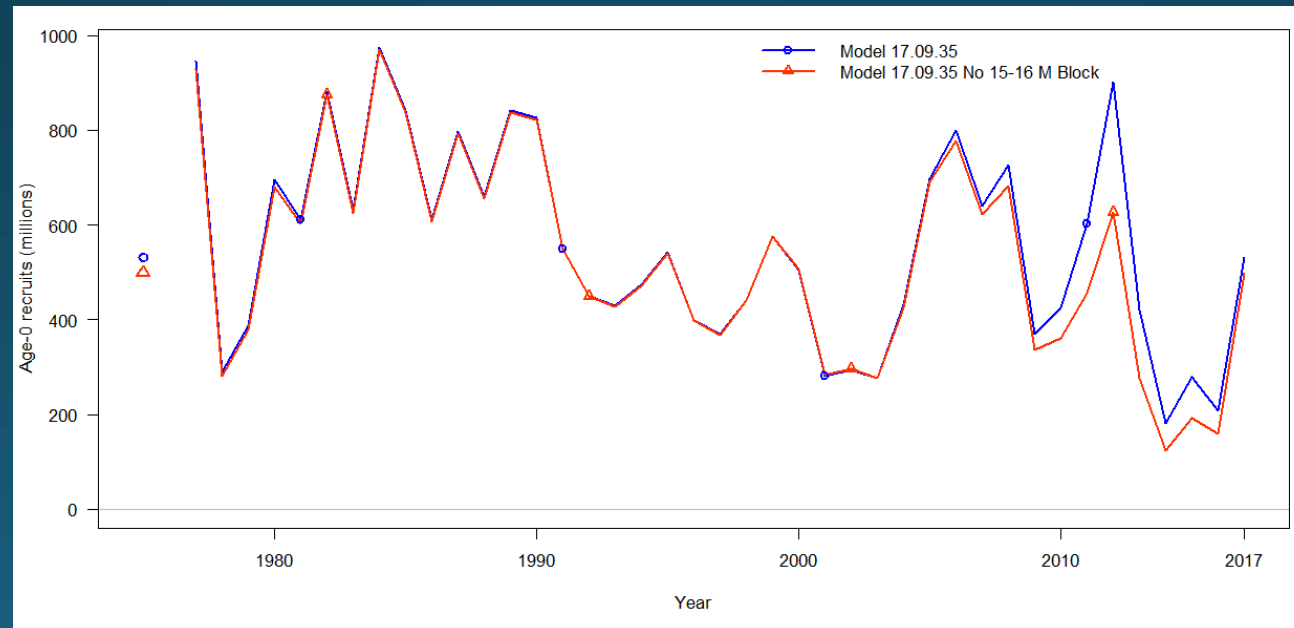
- Peak female spawning biomass in 1990 (190,465 t)
- Lowest female spawning biomass in 2017 (47,326 t)
- 2008 previous low at 54,470 t
- Build up in 2009-2012 based on large 2006-2008 year classes



GOA Pacific cod Model 17.09.35 Projections



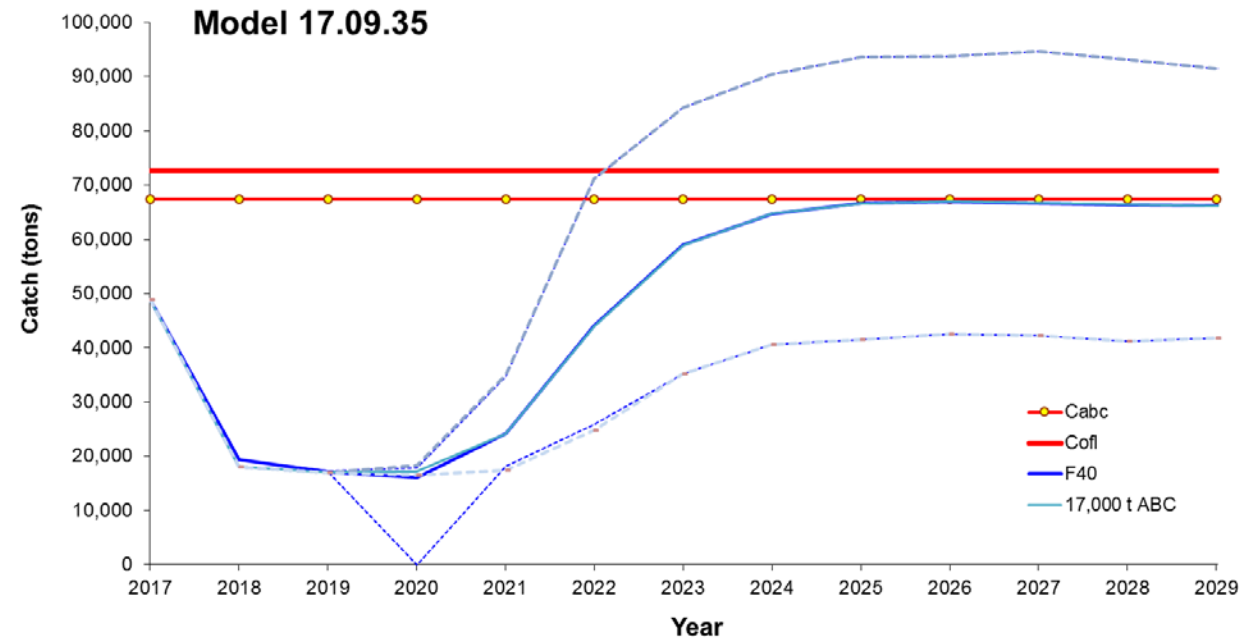
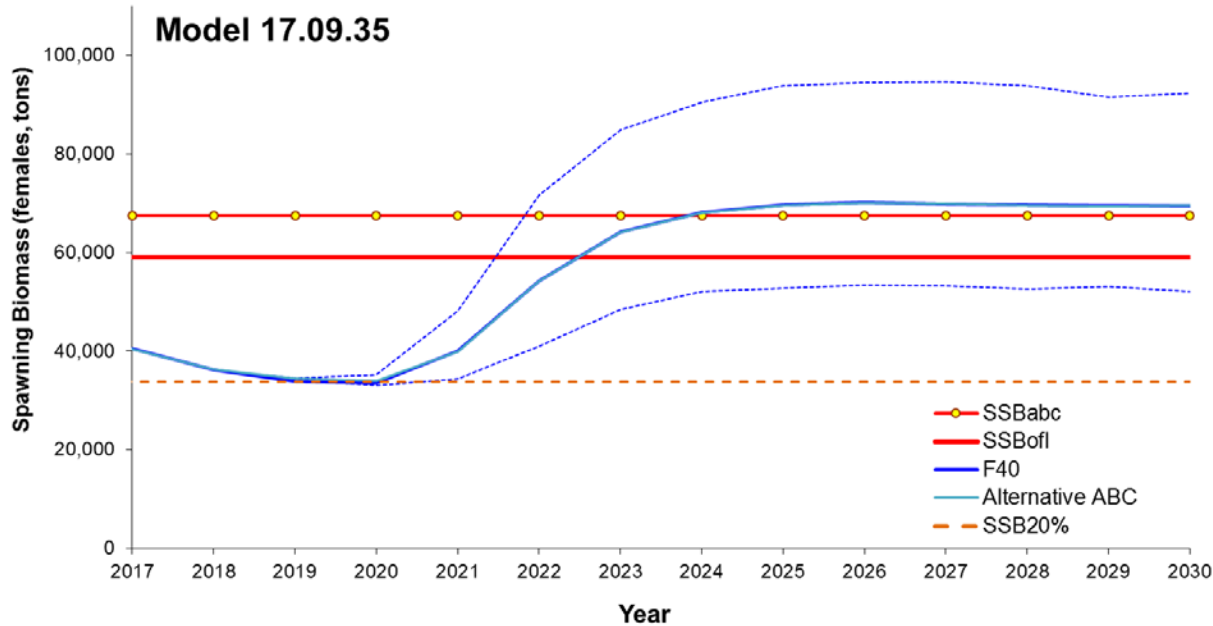
- Based on mean recruitment post-2016
- Projection recruitment based on Model 17.09.35 without the 2015-2016 recruitment block
- Assumed 2016 fishery selectivity



GOA Pacific cod Model 17.09.35 Projections



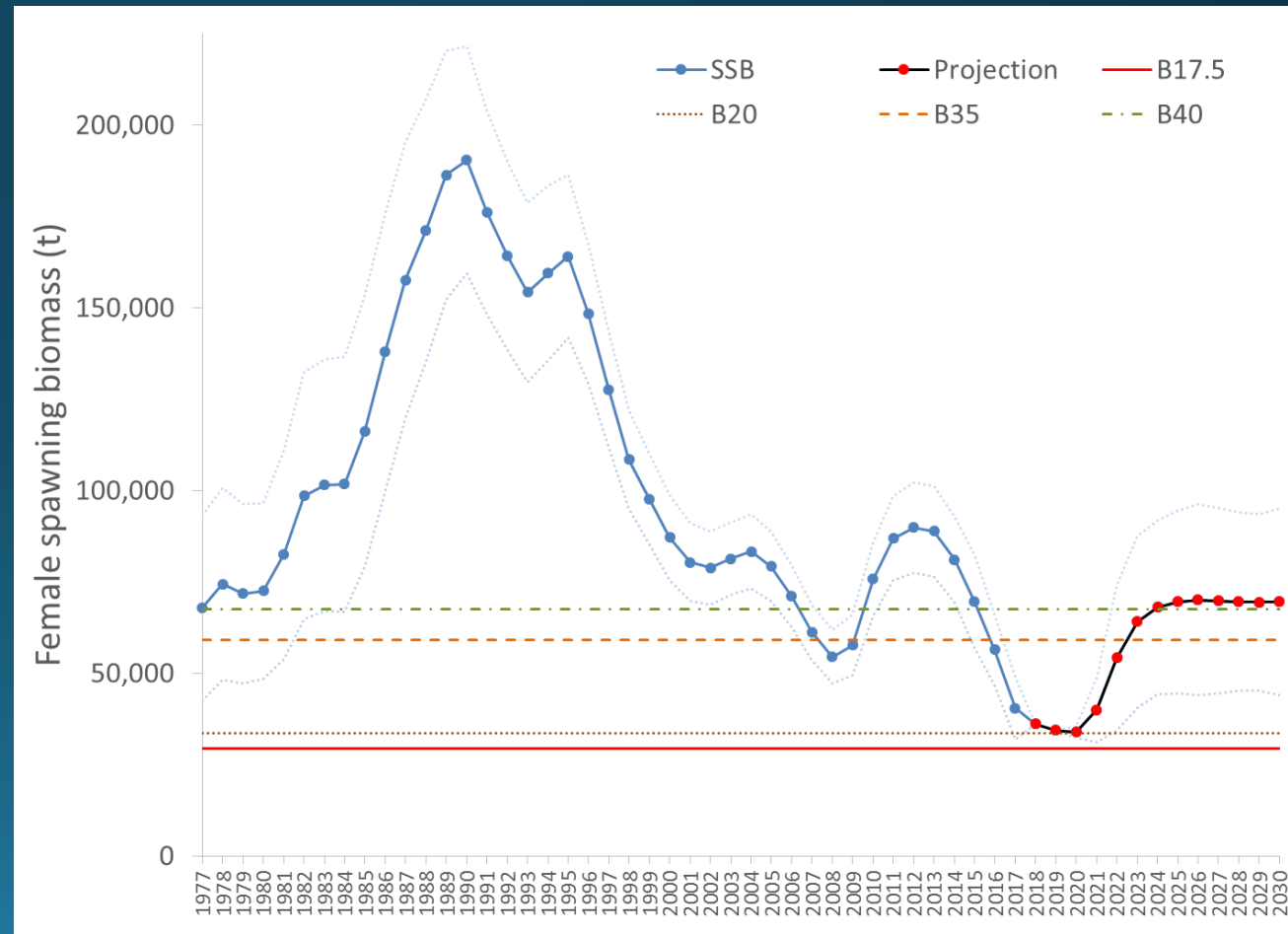
- Approaches $B_{20\%}$
- Requires ABC < Max ABC in 2018 and 2019 to remain above $B_{20\%}$
- Allowable catch below 18,000 t through 2020



GOA Pacific cod Model 17.09.35 Projections



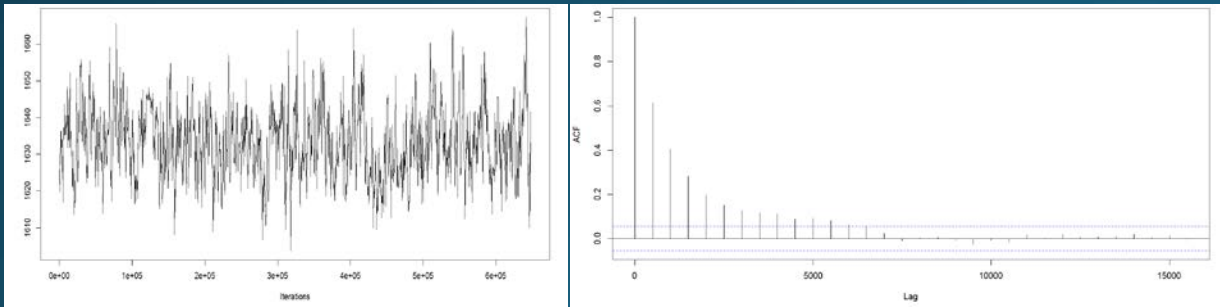
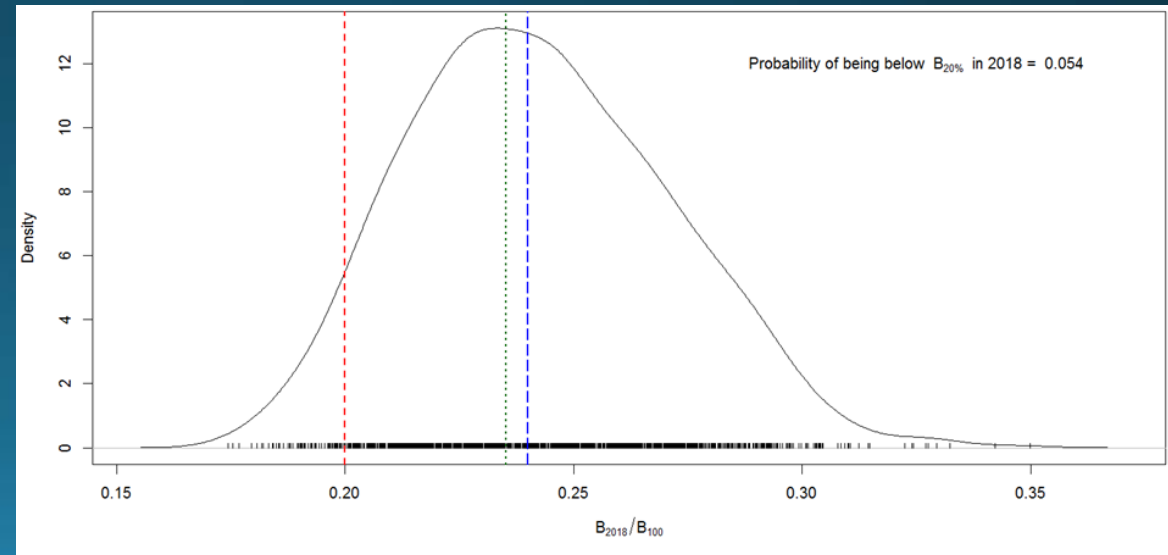
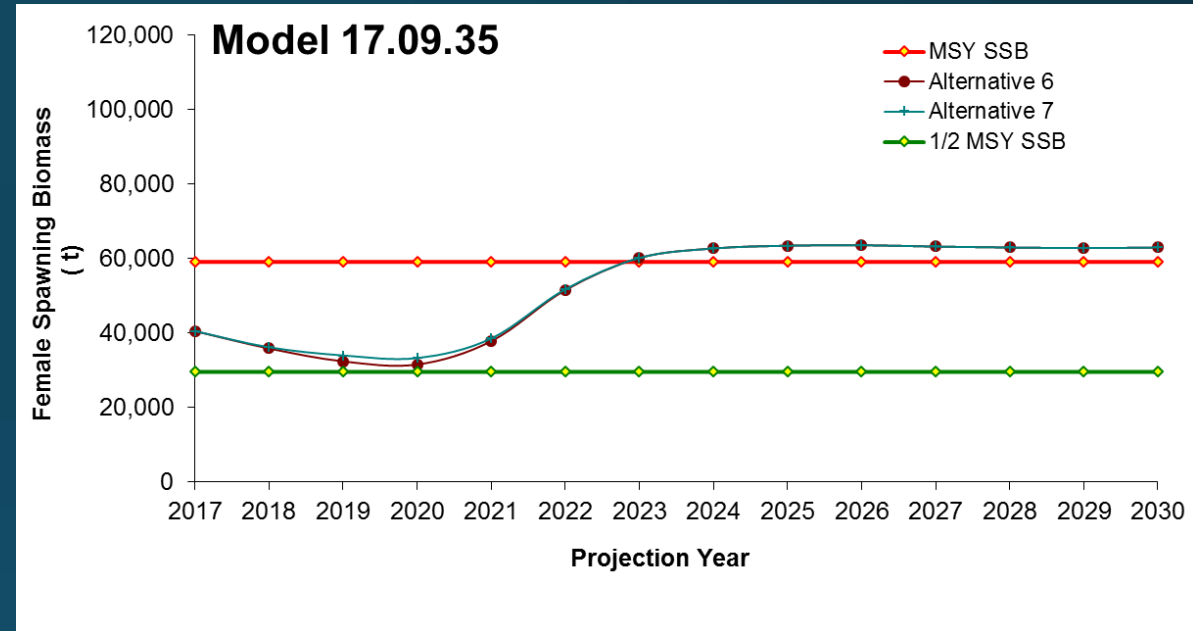
- Projected to reach all-time low in 2020
- Due to high mortality of the 2011 and 2012 age classes and expected poor recruitment 2013-2016
- First increase expected in 2021 given mean recruitment post-2016



GOA Pacific cod Model 17.09.35 Status



- Not overfished, not overfishing...
- MCMC posterior distribution
 - 1,000,000 burn 350,000 thinned 500
 - Stable MCMC
 - Posteriors consistent with MLE
 - 5% probability of being below $B_{20\%}$ in 2018



GOA Pacific cod Status

- Tier 3b ($B_{2018} = B_{21.5\%}$)
- 77% decrease in ABC from last year's projection for 2018
- 61% decrease from 2017 catch
- Area apportionment based on random effects model

Authors' recommended Model 17.09.35

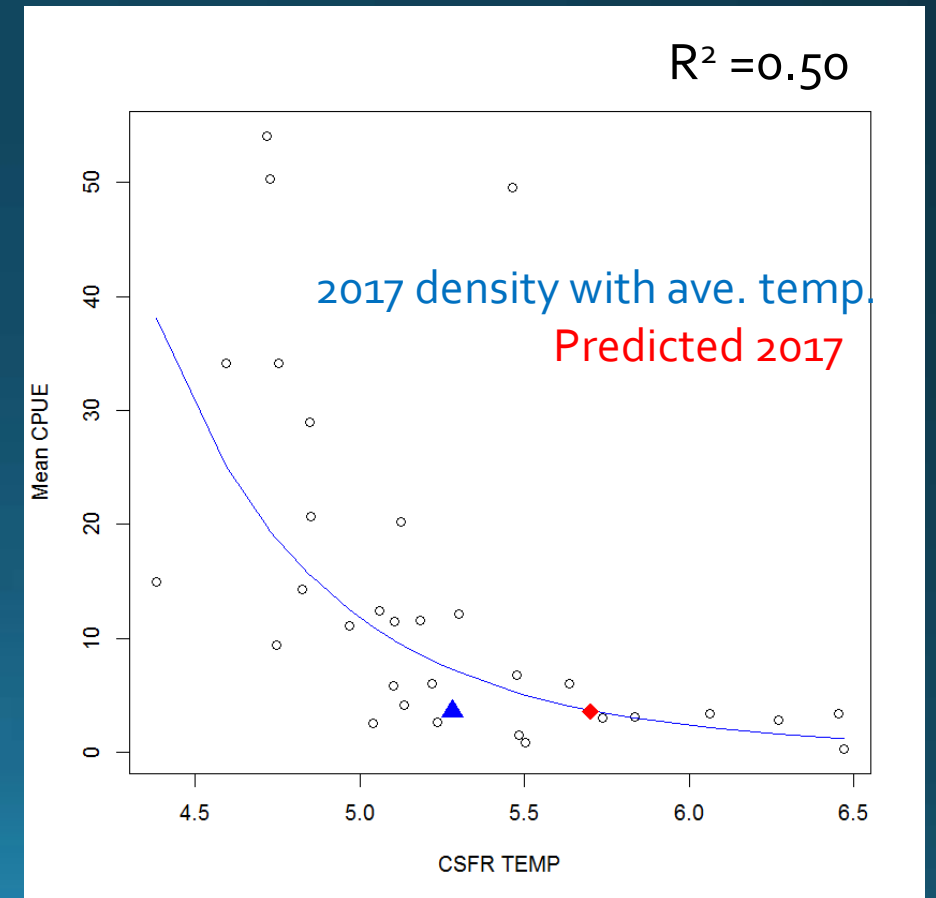
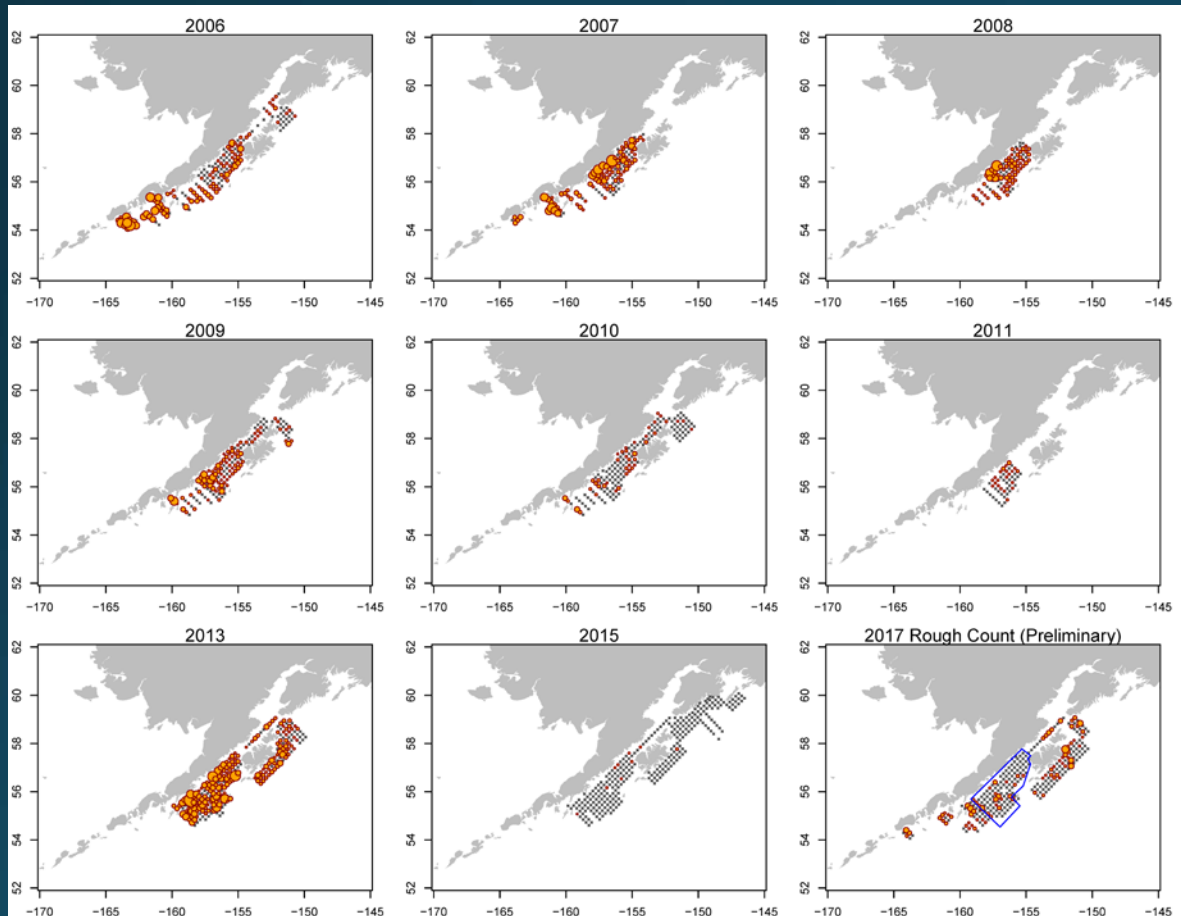
Quantity	As estimated or specified last year for:		As estimated or specified this year for:	
	2017	2018	2018	*2019
M (natural mortality rate)	0.47	0.47	0.49	0.49
Tier	3a	3a	3b	3b
Projected total (age o+) biomass (t)	426,384	428,885	170,565	198,942
Female spawning biomass (t)				
Projected	91,198	98,479	36,209	34,424
$B_{100\%}$	196,776	196,776	168,583	168,583
$B_{40\%}$	78,711	78,711	67,433	67,433
$B_{35\%}$	68,872	68,872	59,004	59,004
F_{OFL}	0.652	0.652	0.42	0.40
$maxF_{ABC}$	0.530	0.530	0.34	0.32
F_{ABC}	0.530	0.530	0.31	0.31
OFL (t)	105,378	94,188	23,565	21,412
maxABC (t)	88,342	79,272	19,401	17,634
ABC (t)	88,342	79,272	18,000	17,000
	As determined this year for:			
Status	2015	2016	2016	2017
Overfishing	no	n/a	No	n/a
Overfished	n/a	no	n/a	No
Approaching overfished	n/a	no	n/a	No

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	44.9	45.1	10.0	100.00
2018 ABC	8,082	8118	1,800	18,000
2019 ABC	7,633	7,667	1,700	17,000


GOA Pacific cod Future outlook

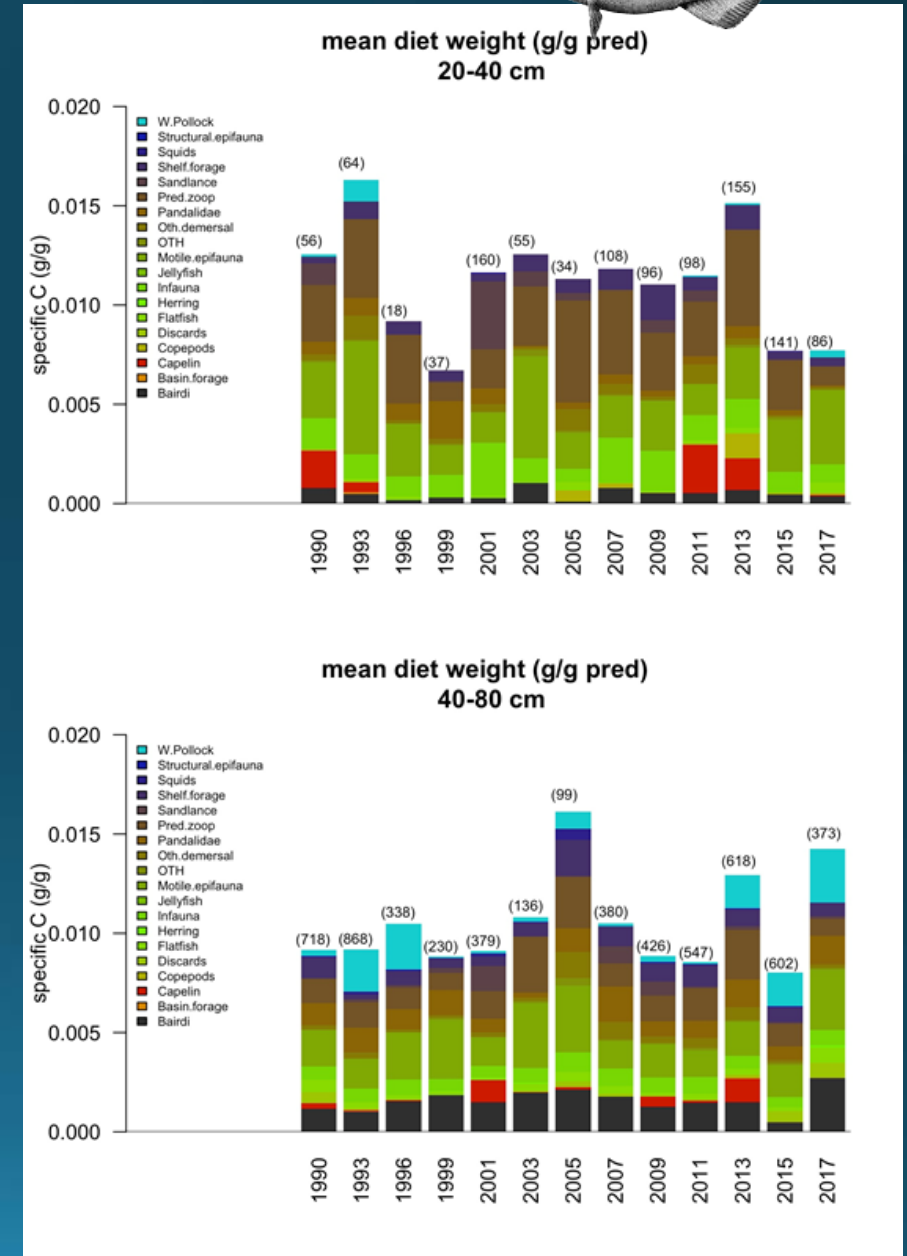
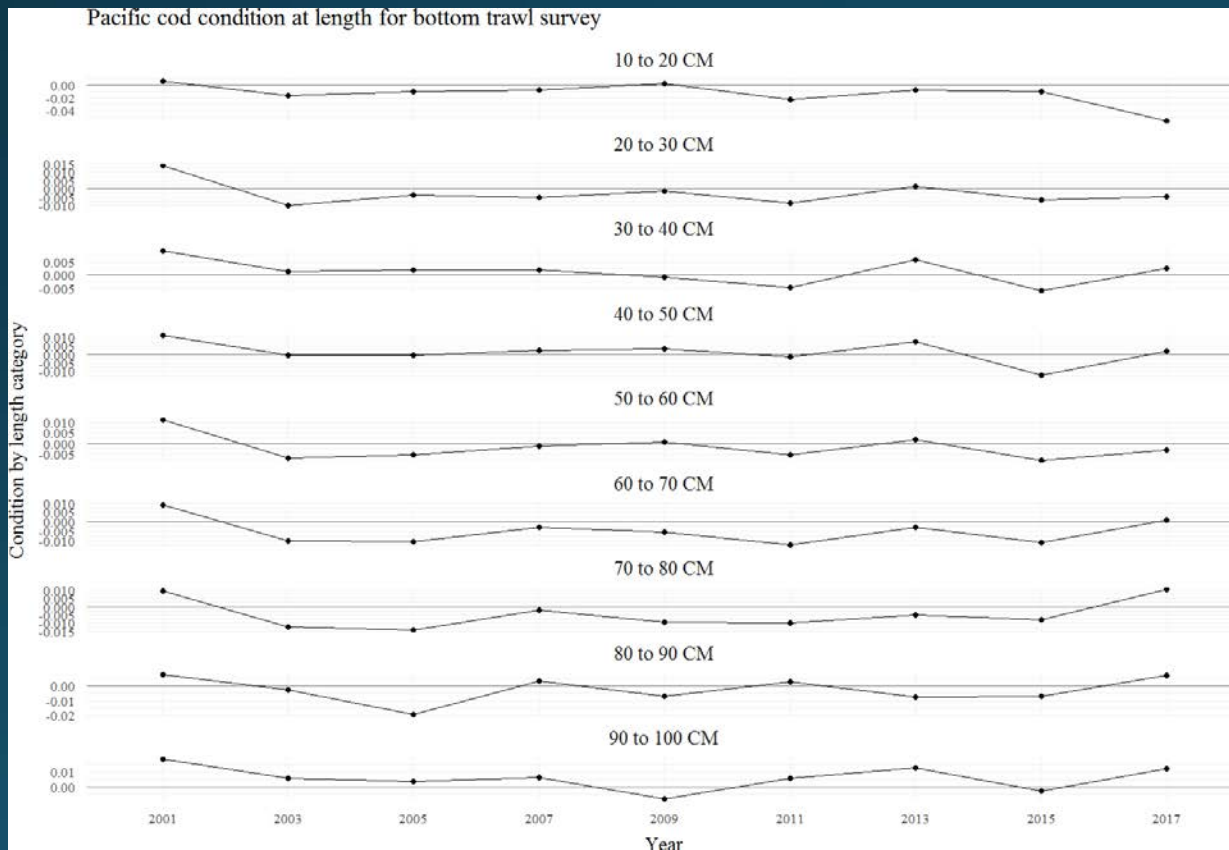


- 2017 larval survey densities look average



GOA Pacific cod Future outlook

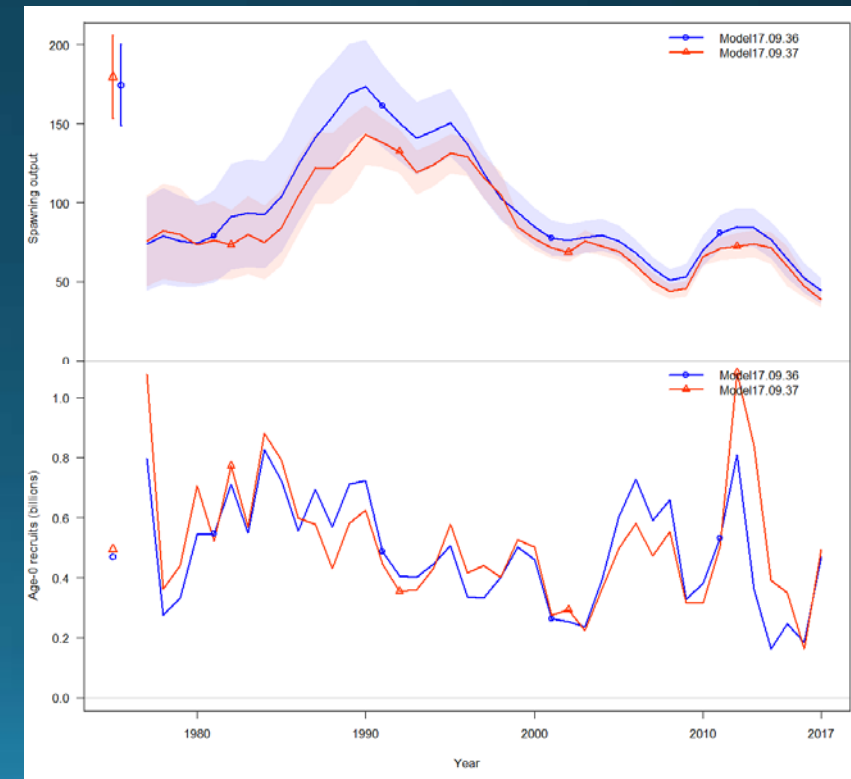
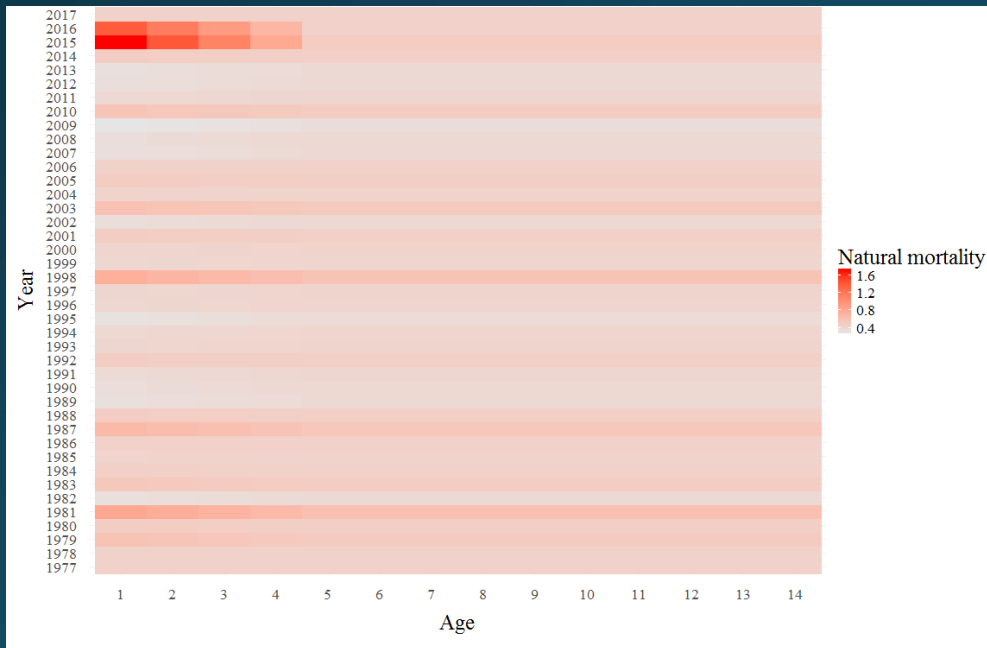
- 2017 stomach analysis
 - small fish remain below average
 - large fish (Pollock, Bairdi, Oth, shrimp )



GOA Pacific cod Model 17.09.37 – Exploratory dynamic M



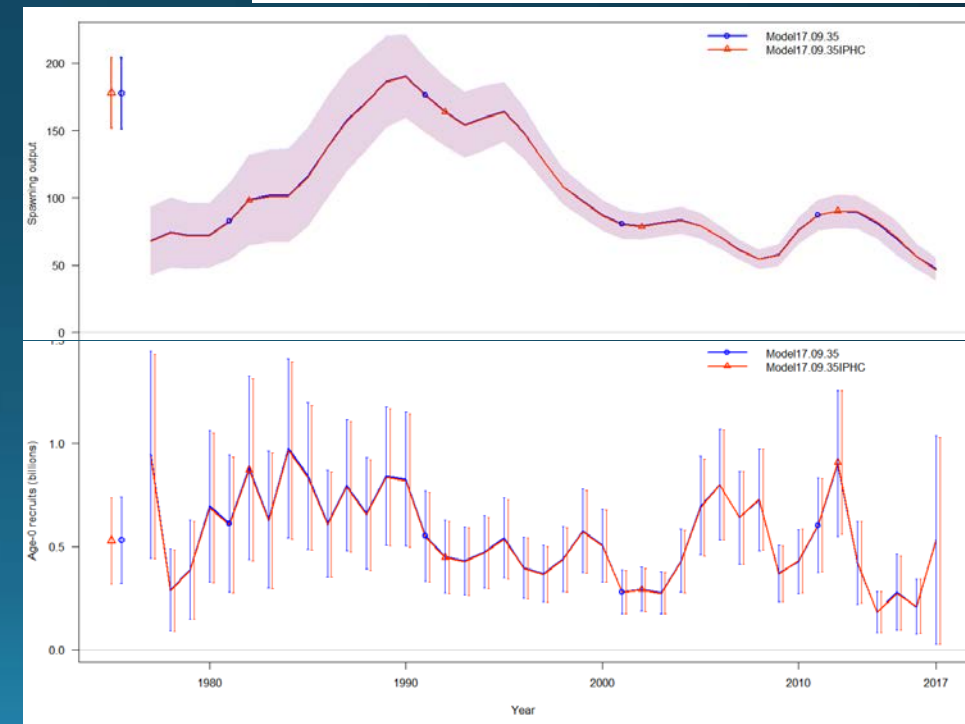
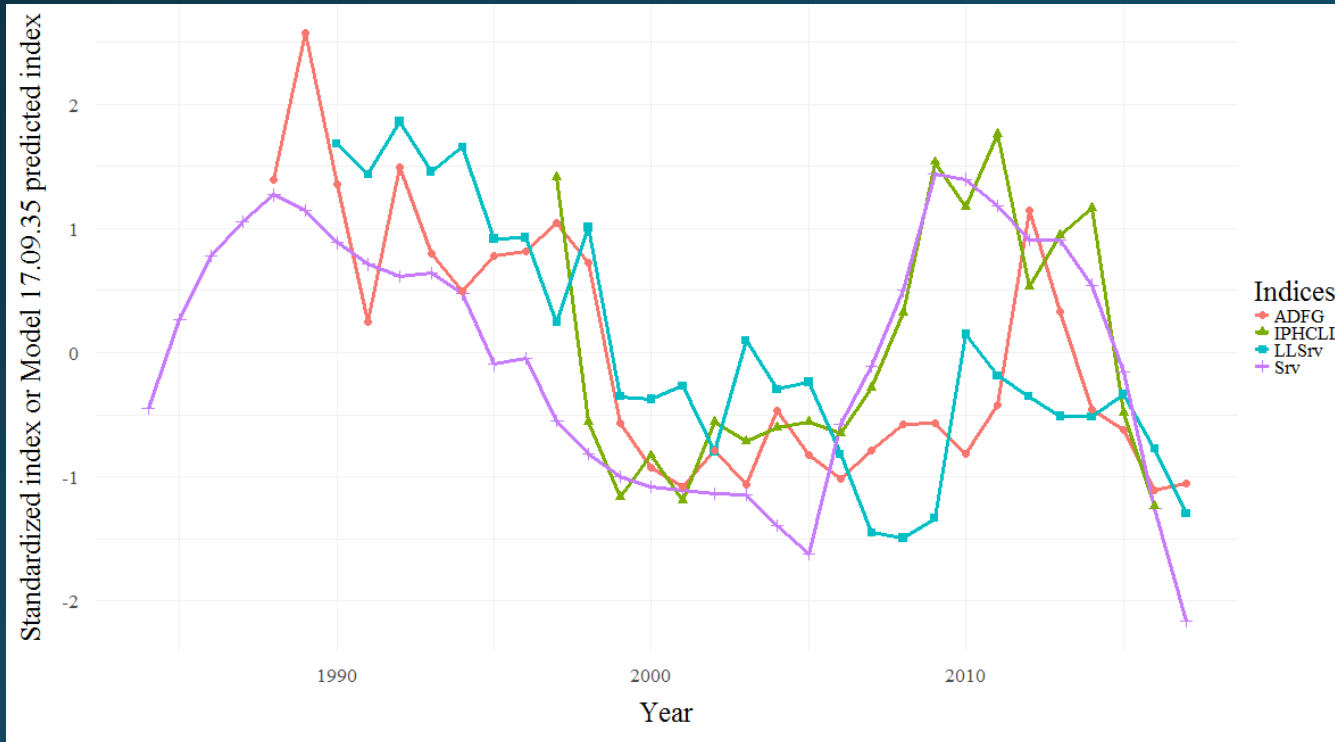
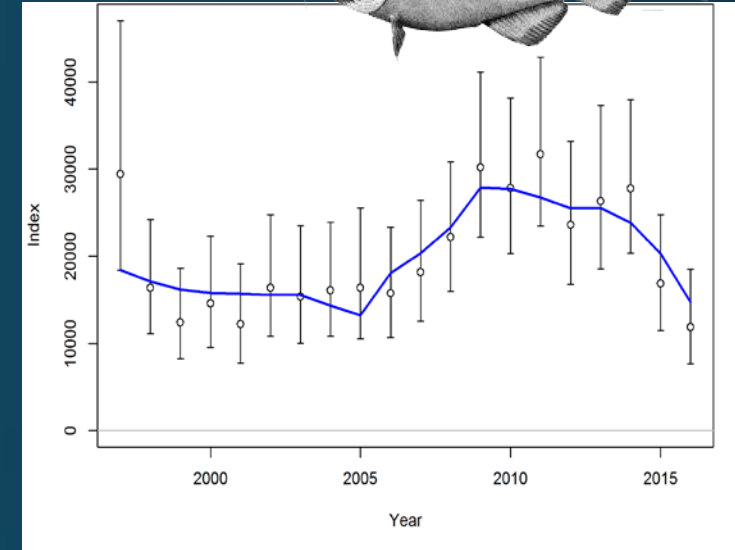
- Knots on M at ages 0, 1, and 5, linear trend between knots
- Annually varying M conditioned on 10 cm CFSR index (age 1 and 5 knots)
 - Average M for ages 1-14 = 0.45
- Not compatible with current projection model



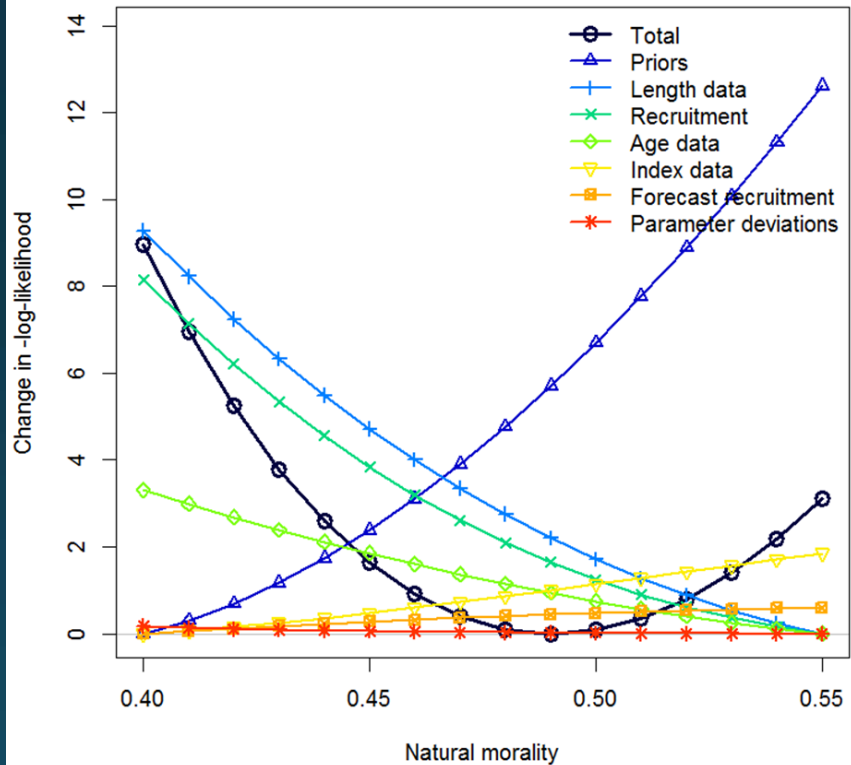
GOA Pacific cod Model 17.09.35 with IPHC survey



- Uses bottom trawl survey selectivity
- Makes little difference in model results
- Should be added to 2018 models



GOA Pacific cod Model 17.09.35 and M



Prior and posterior of M - Model17.09.35

