Science, Service, Stewardship

GOA Pacific cod assessment 2016

Steve Barbeaux, Teresa A’mar, and Wayne Pallson

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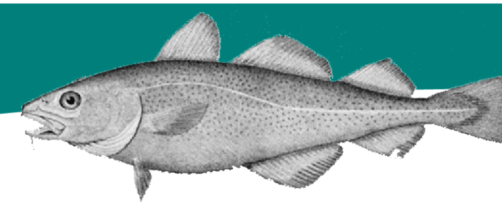
NPFMC Plan Team, Nov. 16, 2016



Brief assessment history

- Stock synthesis (SS) introduced in 1994
- Many models have been developed since with ever increasing complexity
- All models assumed M = 0.37 or (post-2007) 0.38 based on M = $1.65/A_{50}$ (Jensen 1996), A_{50} = 4.35 (Stark 2007).
- Q has been in contention
  - Q = 1.0 (1994-2008 and 2012-2015)
  - Q = 0.916 for 60-81cm (2009-2011)
- Diverse array of selectivity selections over time
  - Seasonal fishery selectivity
  - Age-based vs length-based
  - Time varying
  - Dome-shaped vs. Asymptotic
  - Parametric and nonparametric

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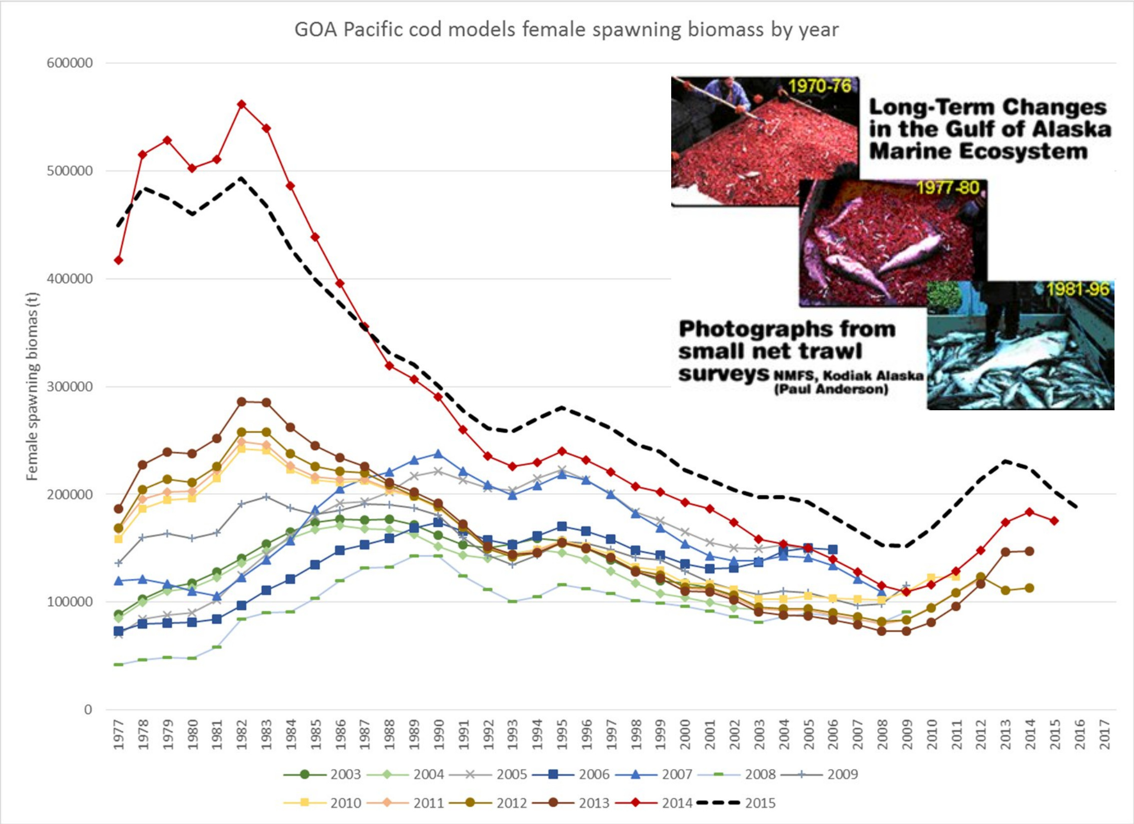
Female spawning biomass estimates since 2003

- High variability in model results
- 2014 and 2015 outside historical bounds



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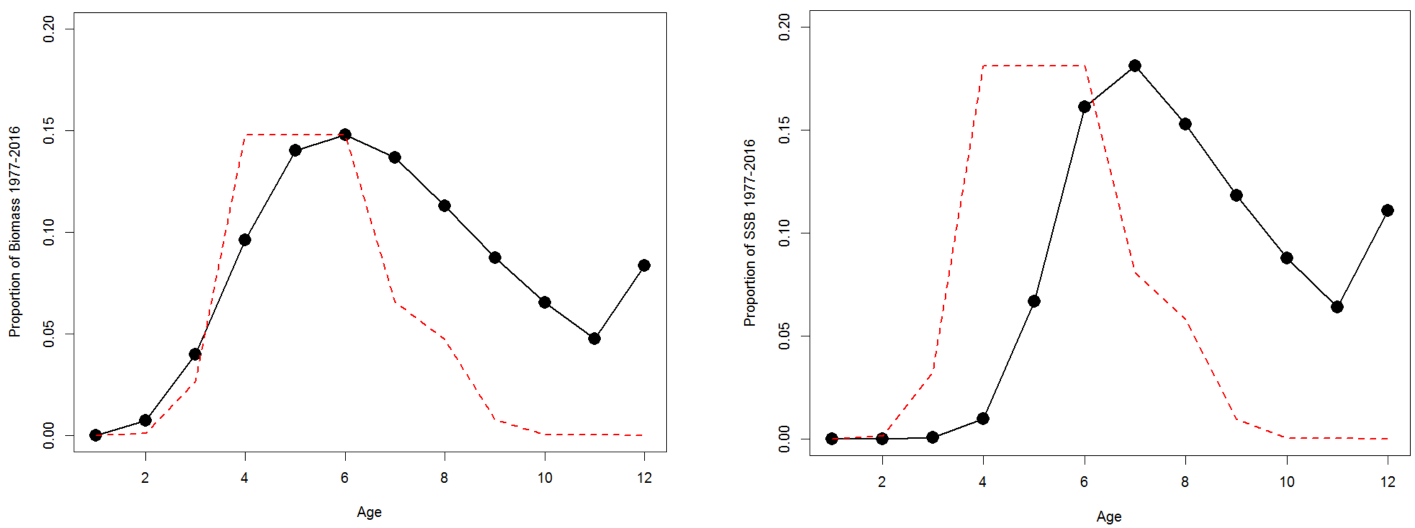
Model 15.3 population assumptions

- M = 0.38 , Q = 1.0
- Seasonal selectivities for fisheries
- Steeply "dome-shaped" selectivity in survey
- Growth L_∞ = 98 cm, K = 0.17
- Large portion of the spawning stock biomass is cryptic (43% ≥ age 8)



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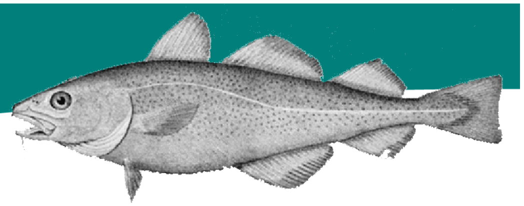
Further Model 15.3 results

- 1990-2015 Model 15.3 was on average 330% higher than survey biomass estimate.



My approach for 2016

- Simplify initial model
  - Better understand inherent assumptions
  - Ascertain reasonable bounds on estimates
- Expand from the base model
  - Make all new assumptions explicit
  - Evaluate impact of each new model component
- Use suite of models for management
  - Choose single “best” for setting harvest specs
  - Use others to bound uncertainty in results

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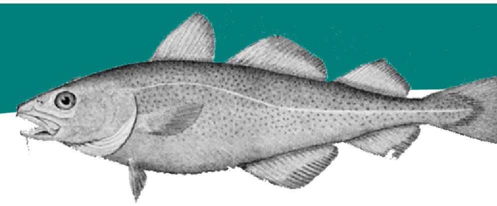
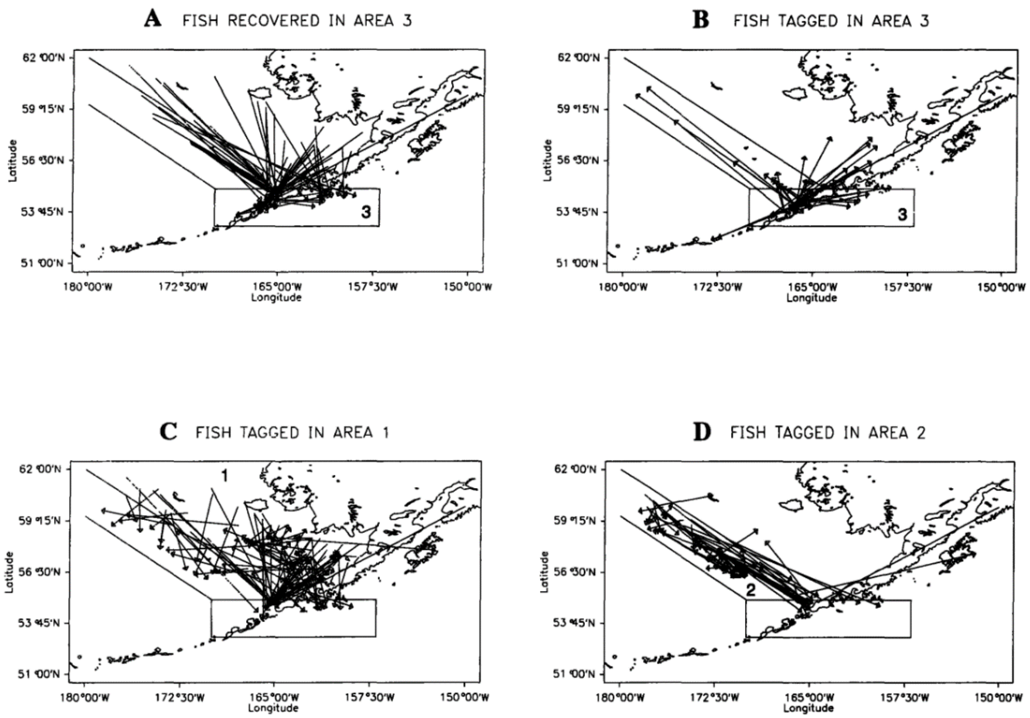


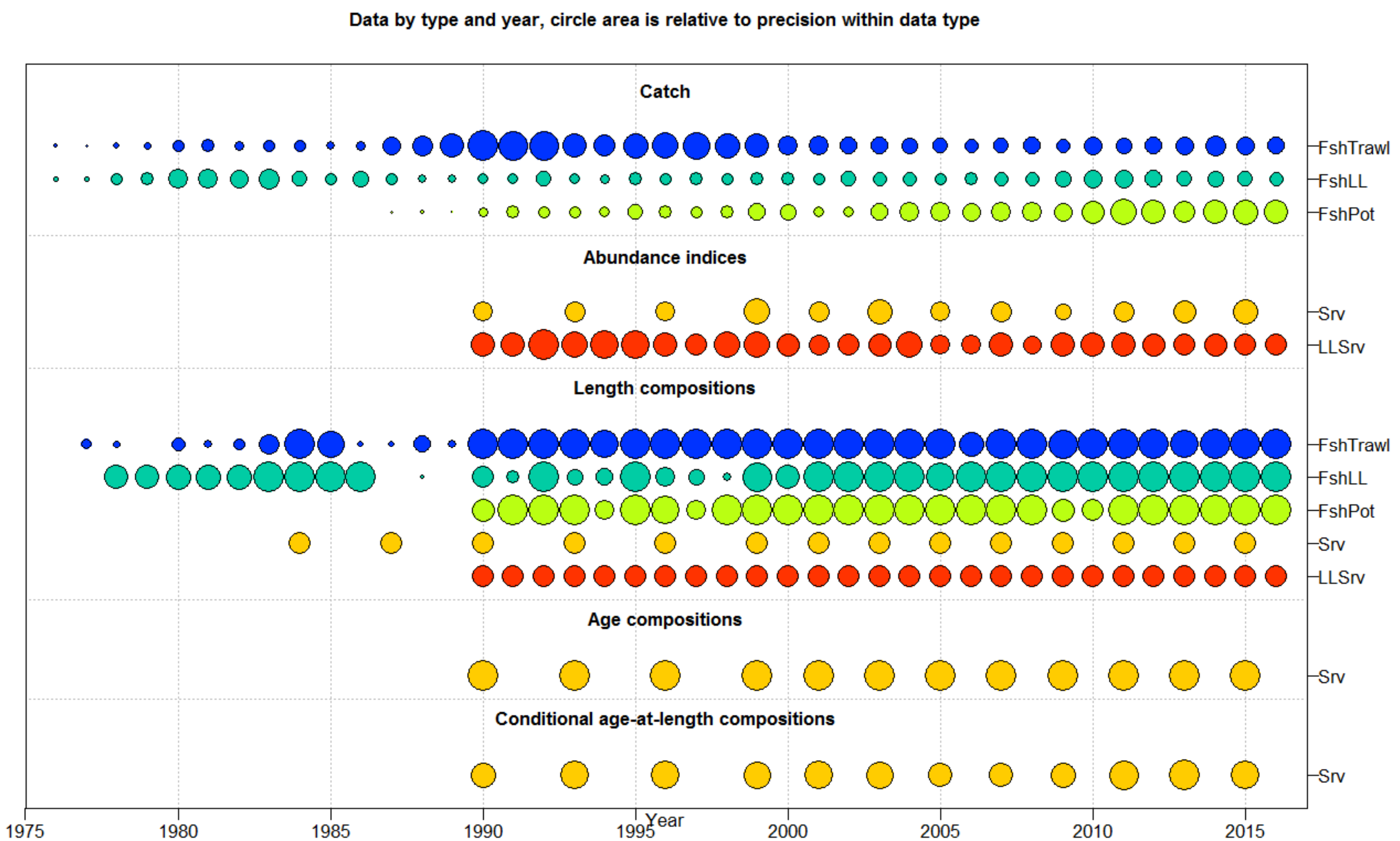
Starting Population Assumption

Gulf of Alaska Pacific cod

- GOA cod is distinct frc those further south (Cu
- Evidence for separatic (Spies 2012).
- AI cod are distinct fron
- GOA cod and Unimak closely related (Cunnir
  - Supported by taggin Shi et al. 2004).



Base Data


Data by type and year, circle area is relative to precision within data type
Catch
FshTrawl
FshLL
FshPot
Abundance indices
Srv
LLSrv
Length compositions
FshTrawl
FshLL
FshPot
Srv
LLSrv
Age compositions
Srv
Conditional age-at-length compositions
Srv
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

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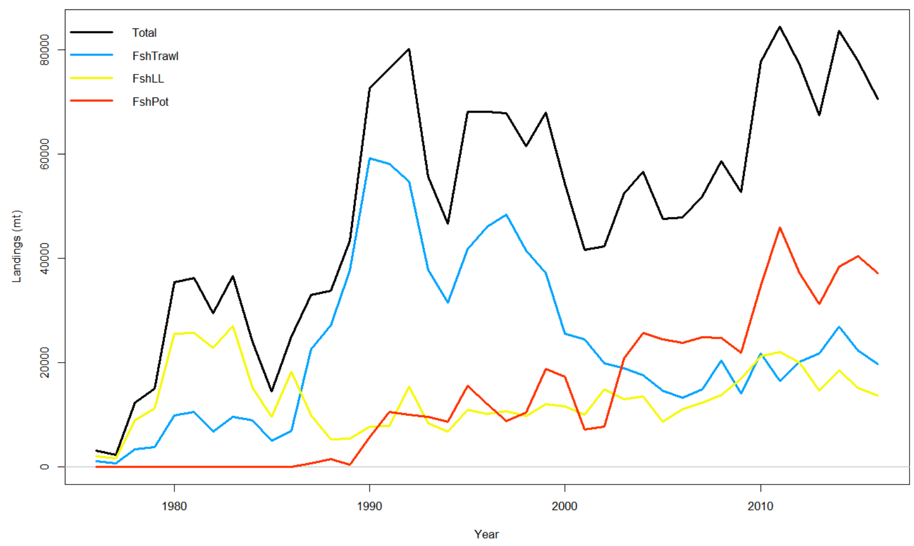
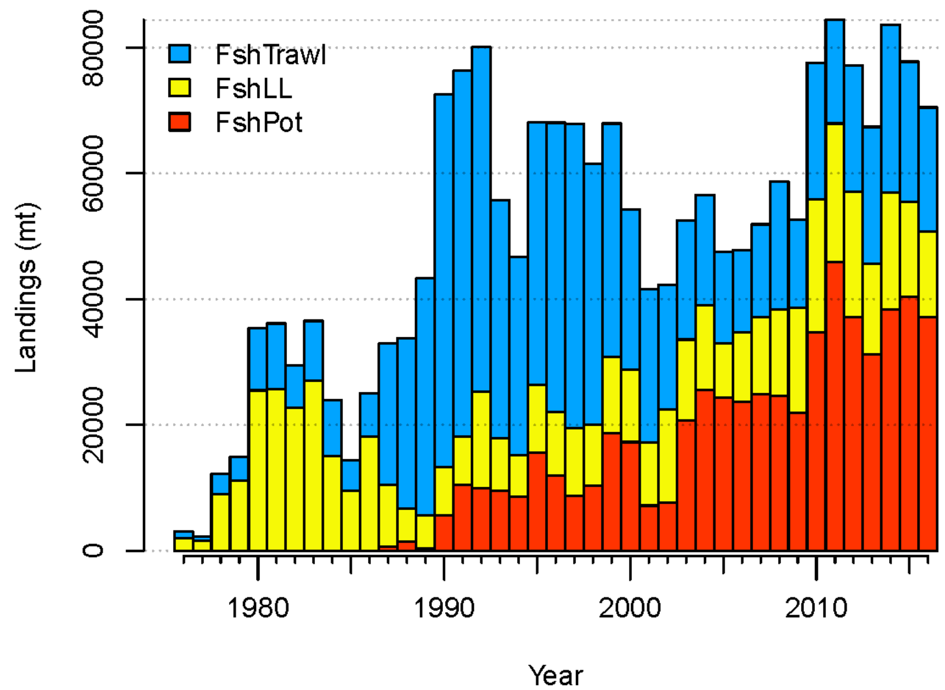
Fishery catch data

- Aggregated by gear (trawl, longline, and pot) and year
  - Catch 1977-2016
  - Highest catch in 2011 at 84,385 t





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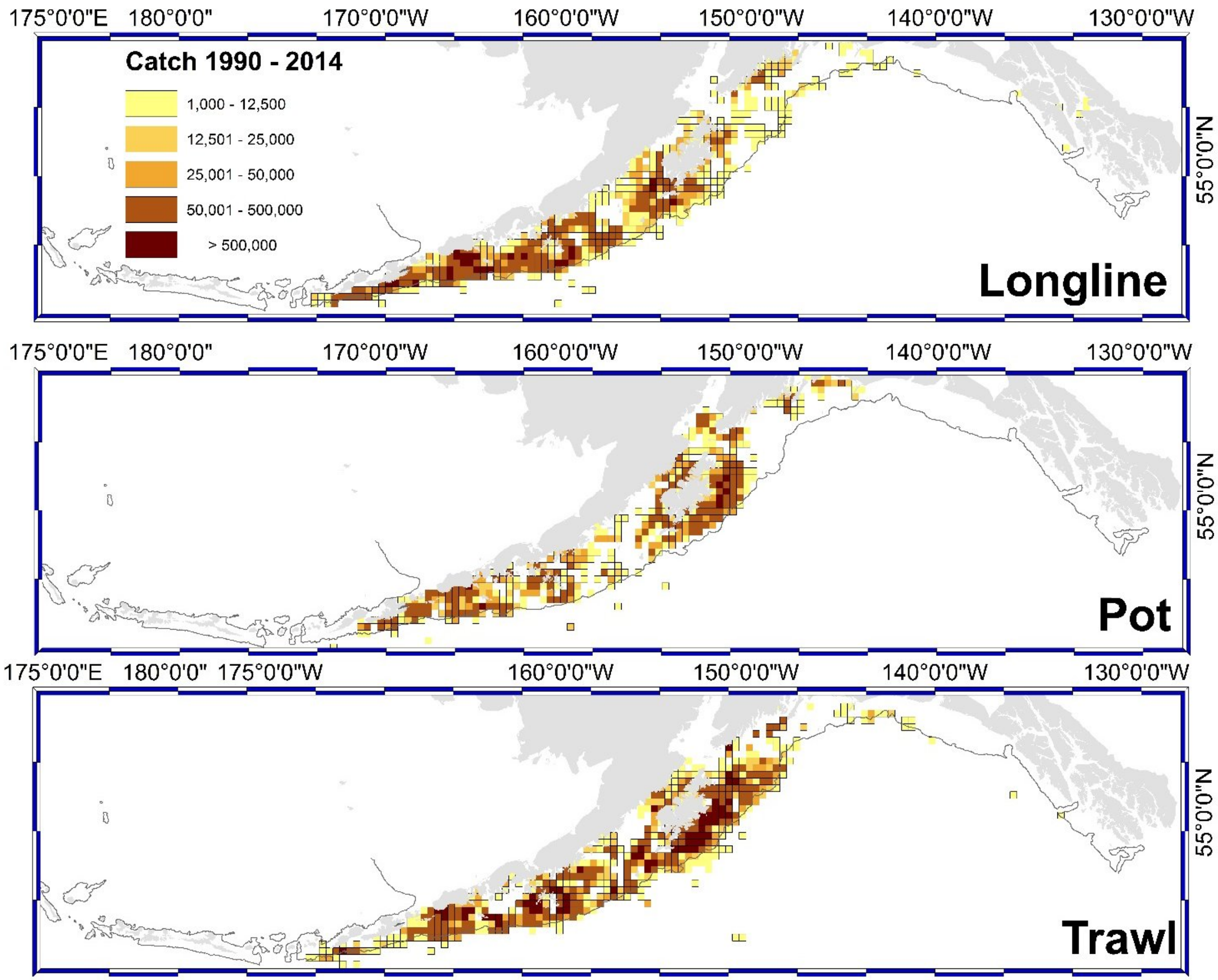
Historical catch distribution 1990-2014



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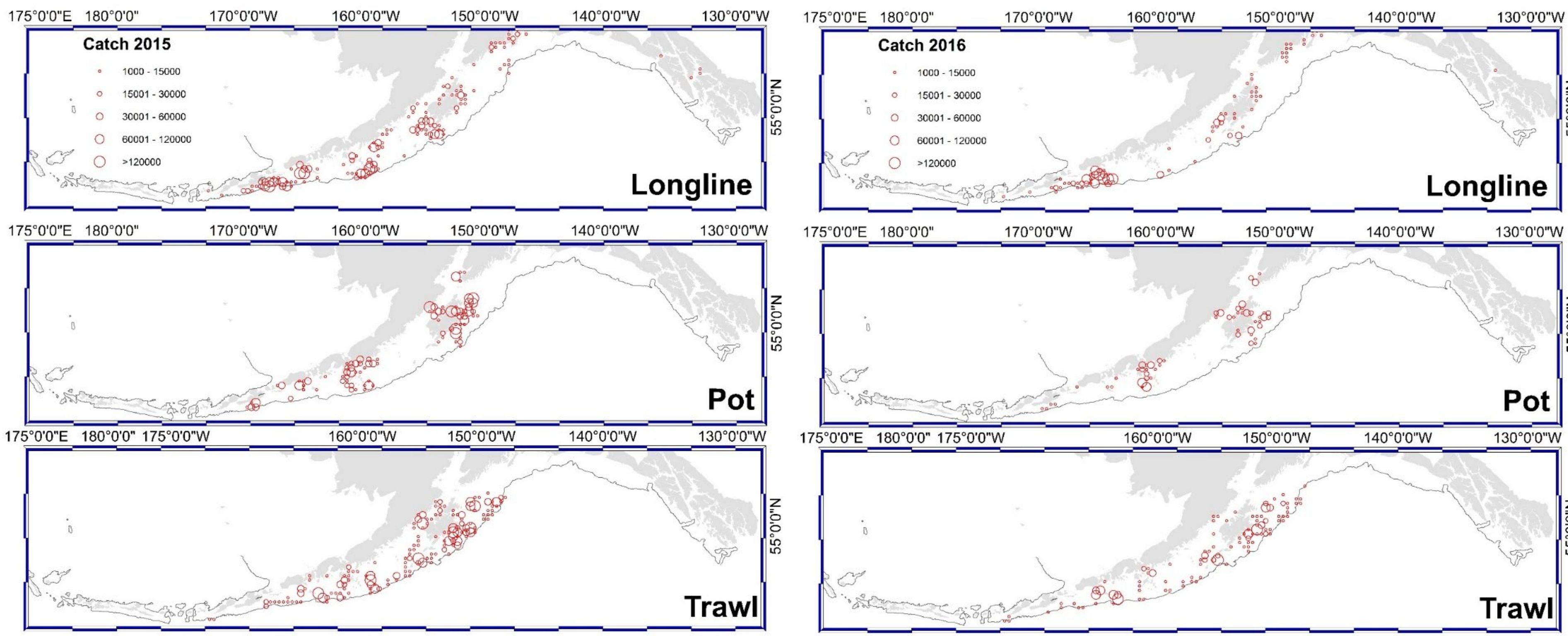
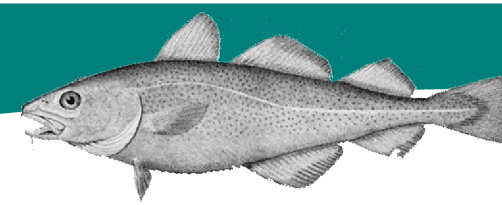
Catch distribution 2015 and 2016

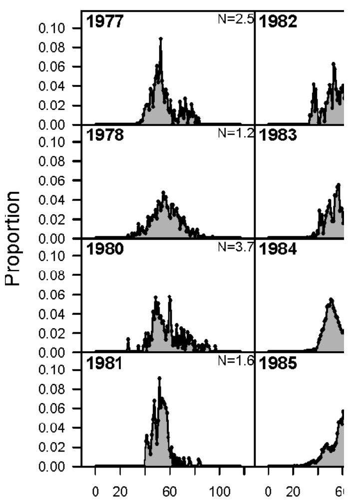


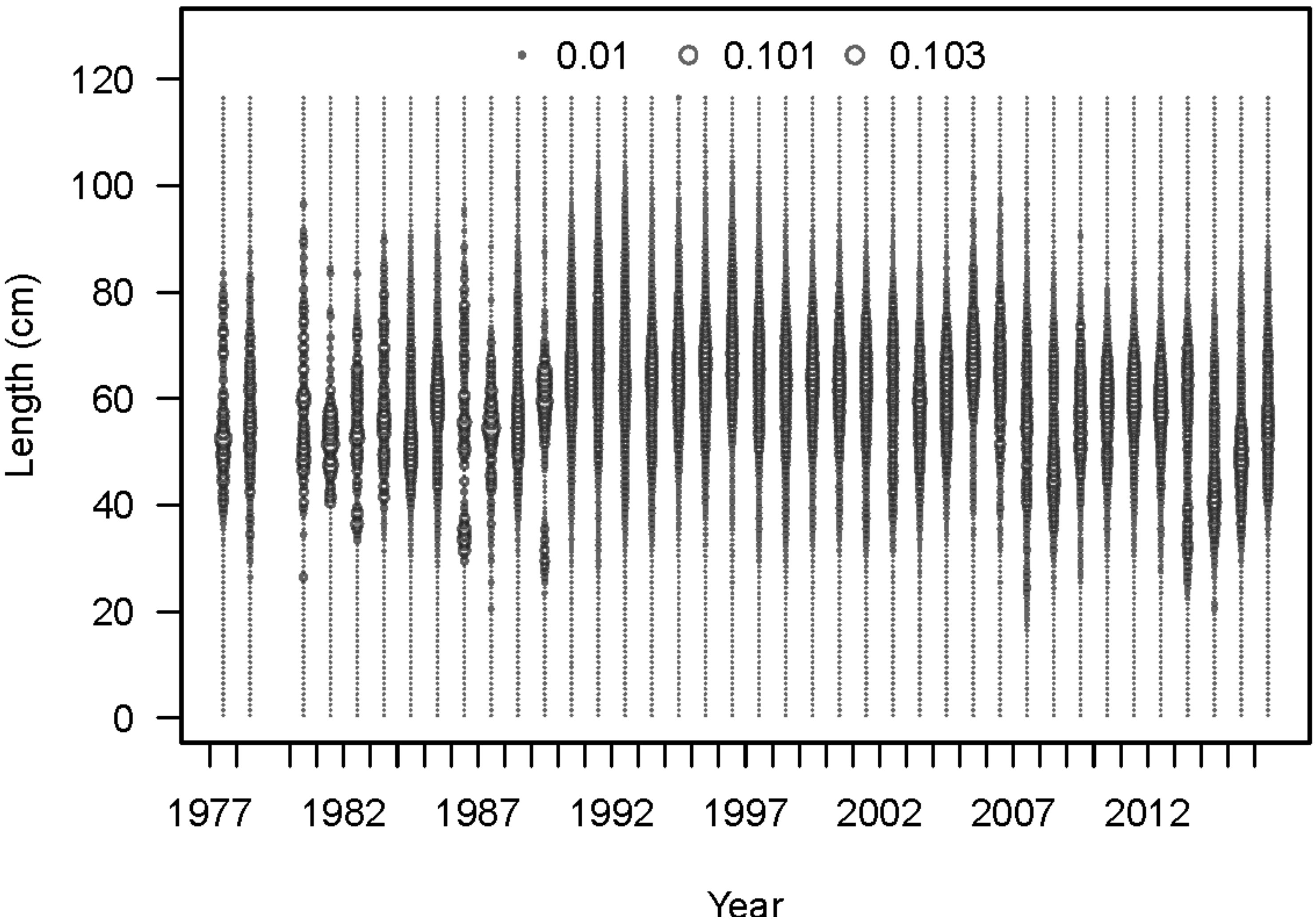


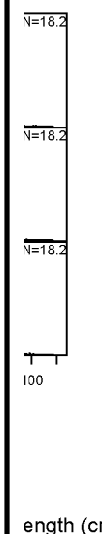
Fishery length composition data

- Fishery data aggregated by sex, gear (trawl, longline, and pot), and year
  - One season in proposed models
  - Data binned from 0.5 cm to 116.5 cm at 1 cm
  - Length composition observer and ADF&G data weighted by seasonal catch by gear
    - Multinomial sample size as number of hauls or 200, whichever was least

Trawl fishery 1977-2016







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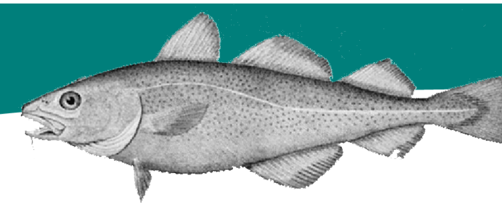
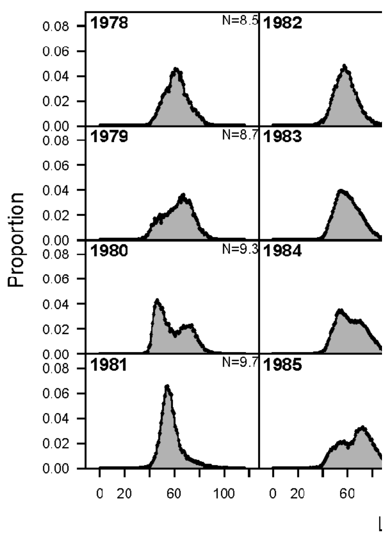
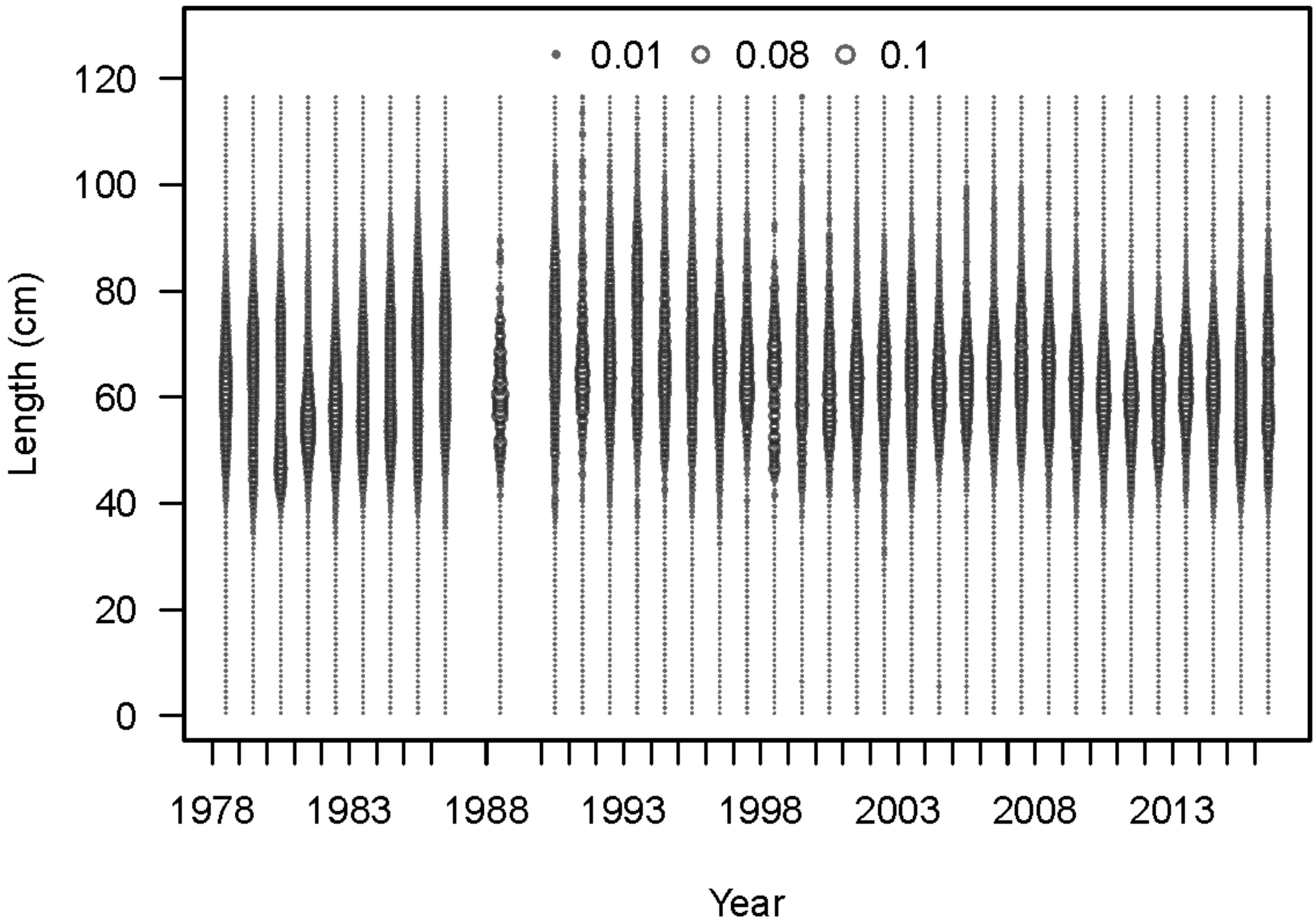
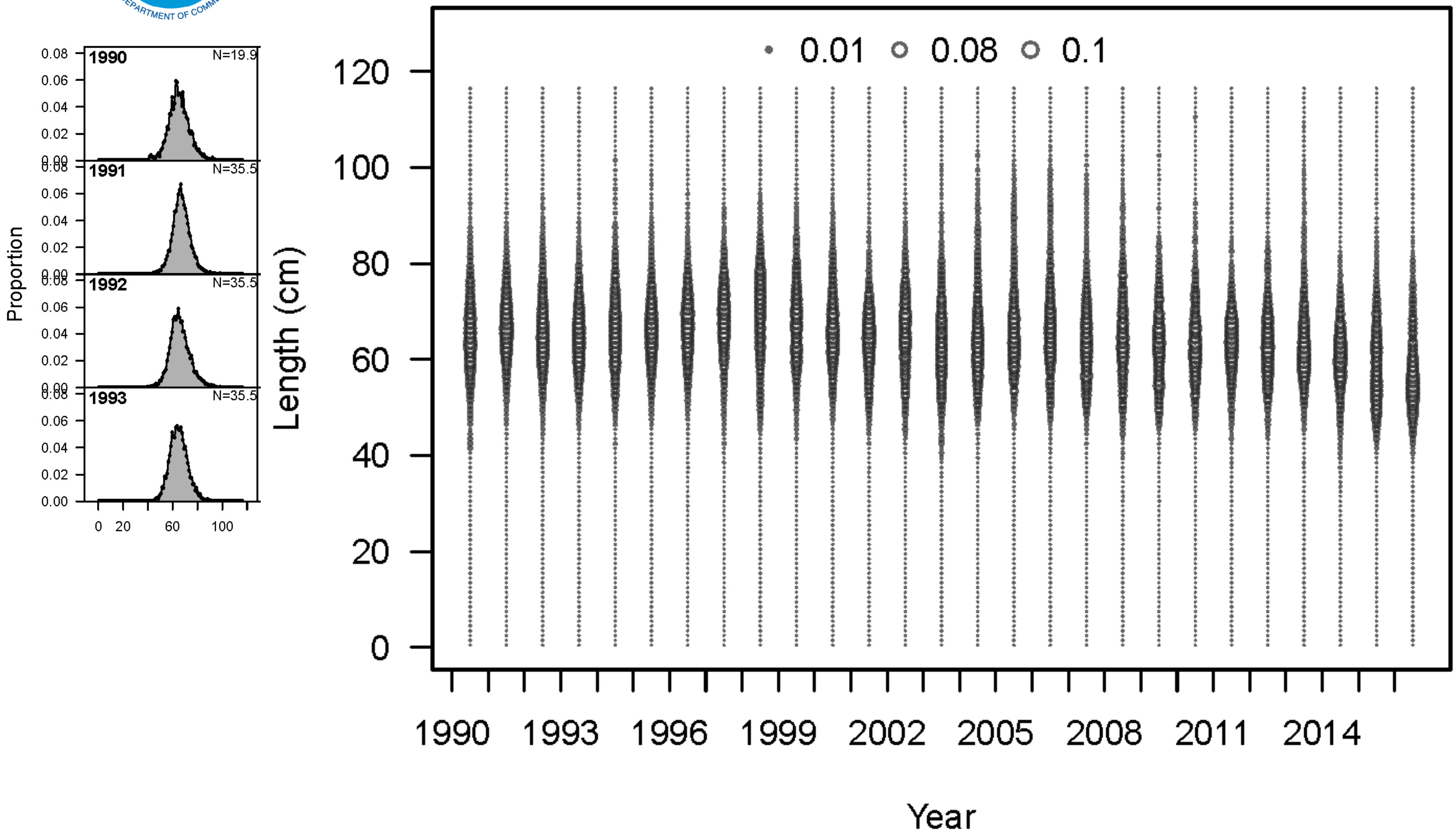


Longline fishery 1978-2016





Pot fishery 1990-2016



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NMFS Summer bottom trawl survey data

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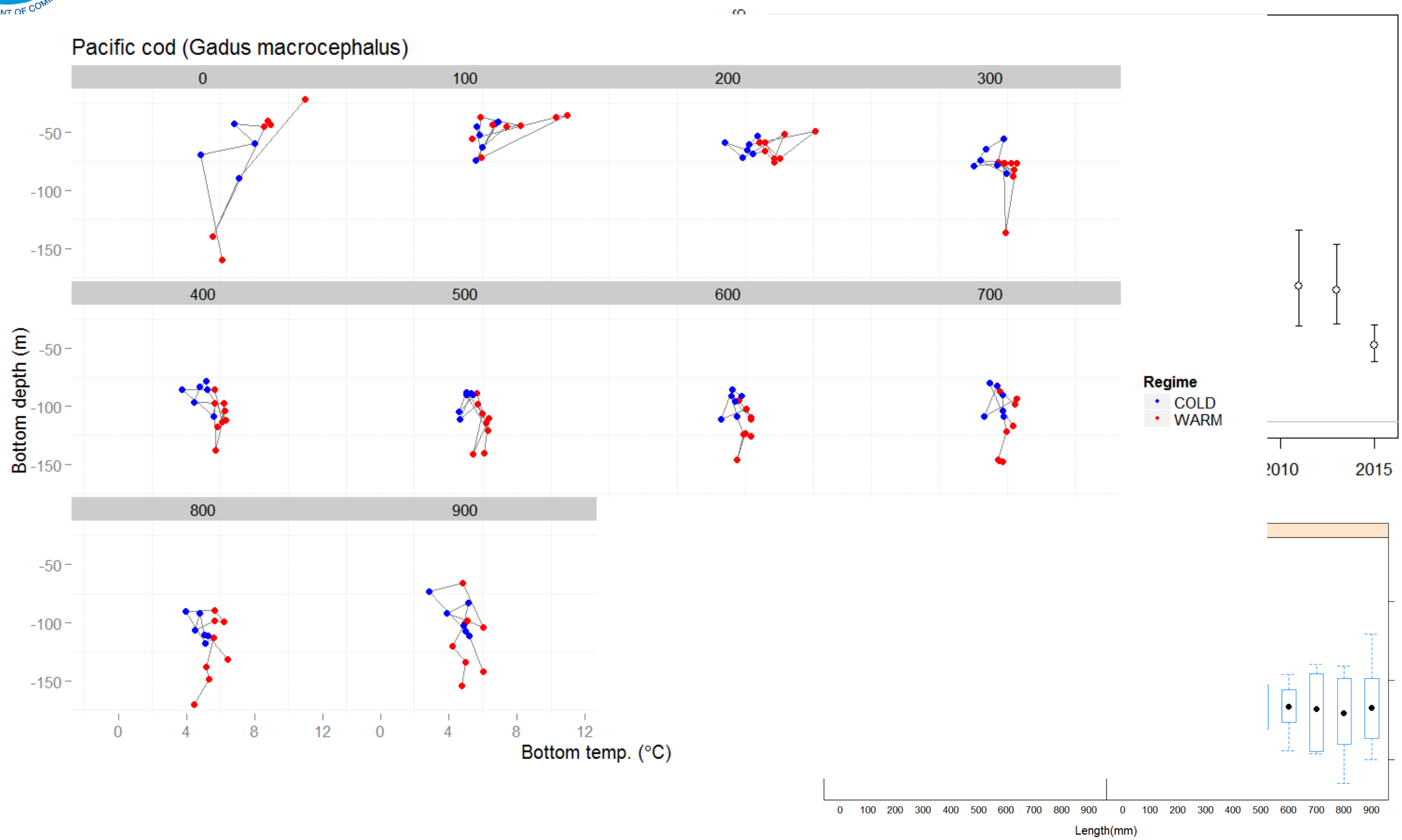
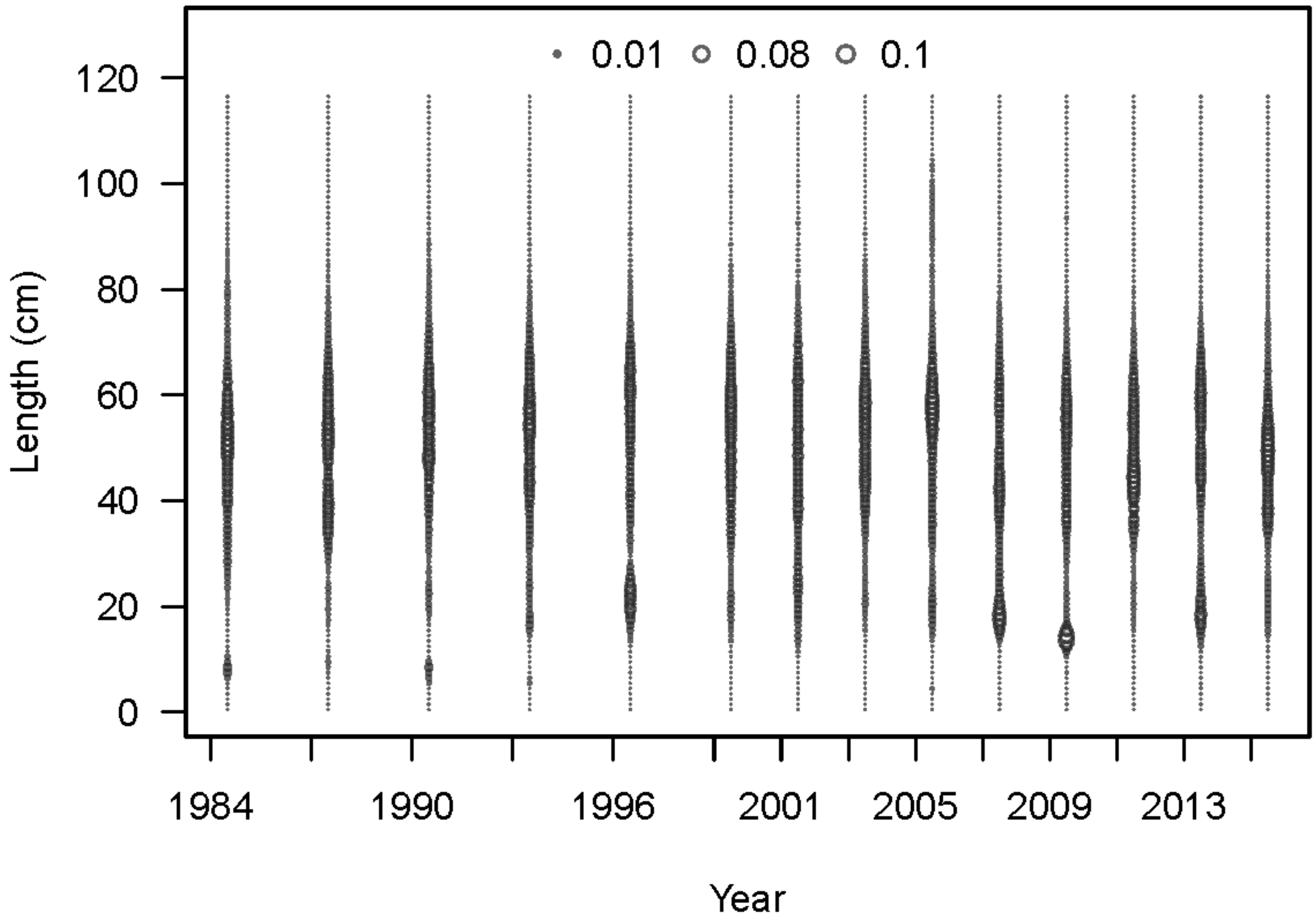


NMFS Summer bottom trawl survey length composition data



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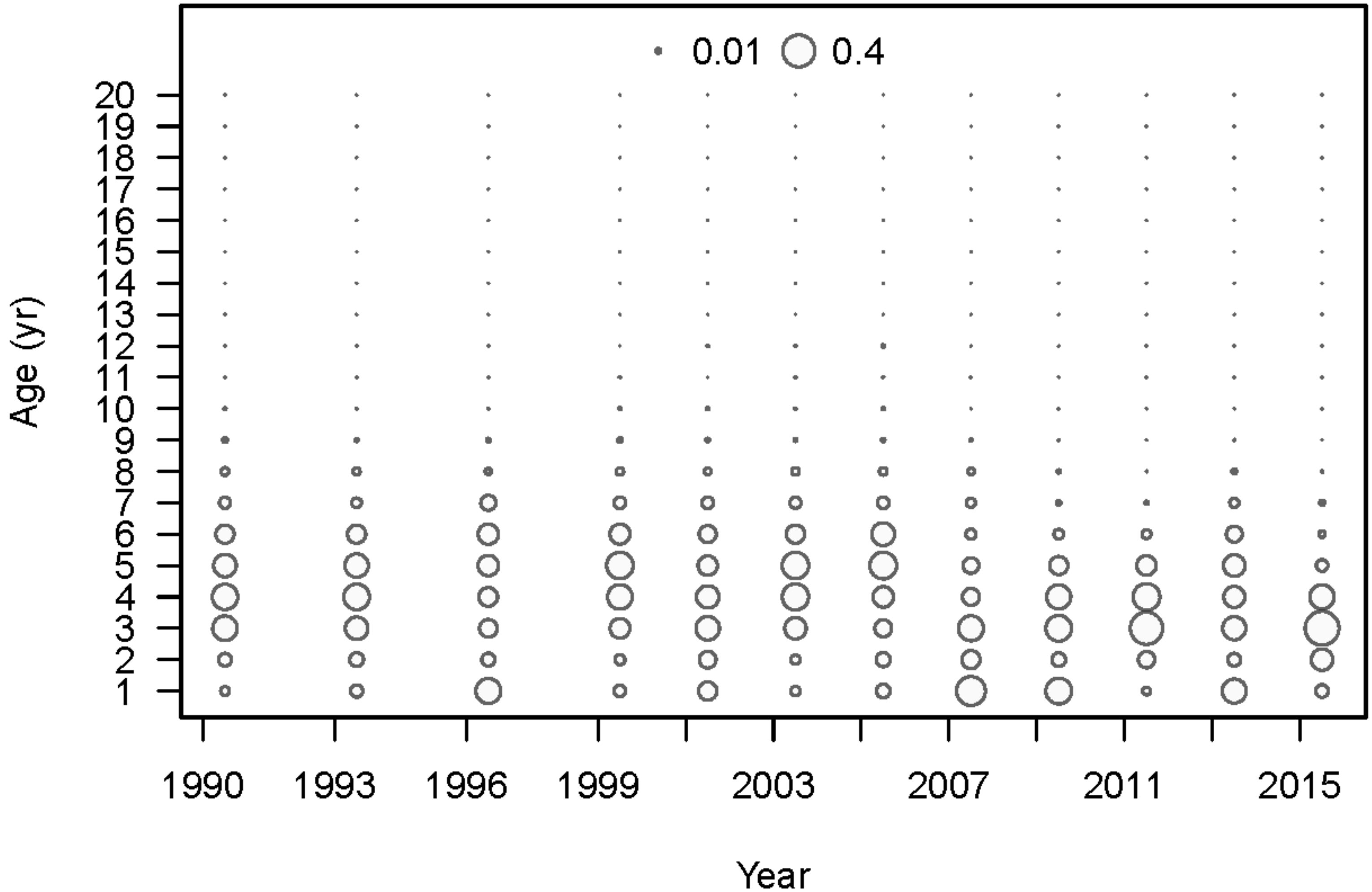
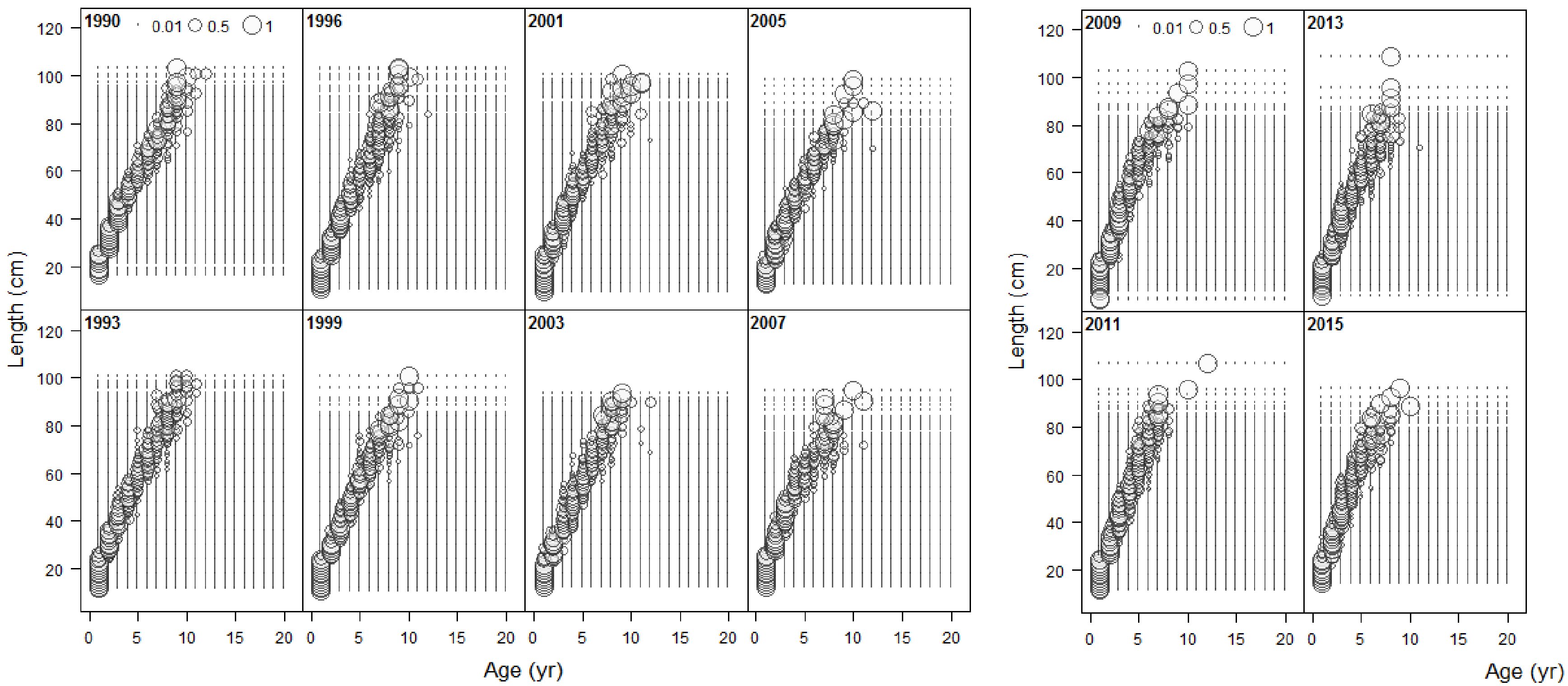
NMFS Summer bottom trawl survey age composition data



NMFS Summer bottom trawl survey conditional age-at-length data



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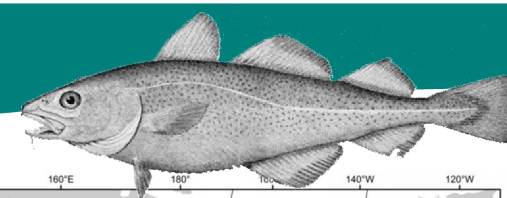
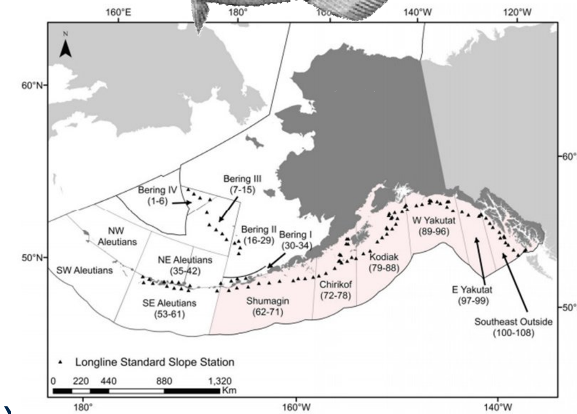
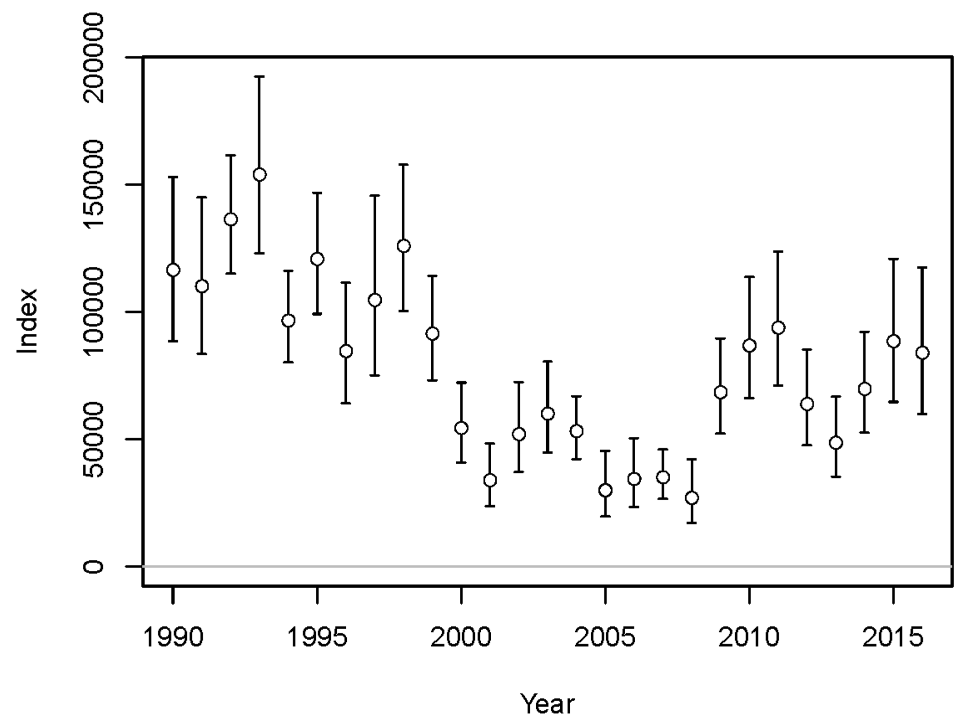
NMFS longline survey





- 1990 - 2016 Relative Population Numbers (RPN)
- 1990 - 2016 length composition data
- Stuttered ↓ 1990 - 2009
- Steep ↑ 2009 - 2011
- Small ↓ 2012 - 2013
- Steady ↑ 2013 - 2018
- 2016 ↓ 5% from 2015



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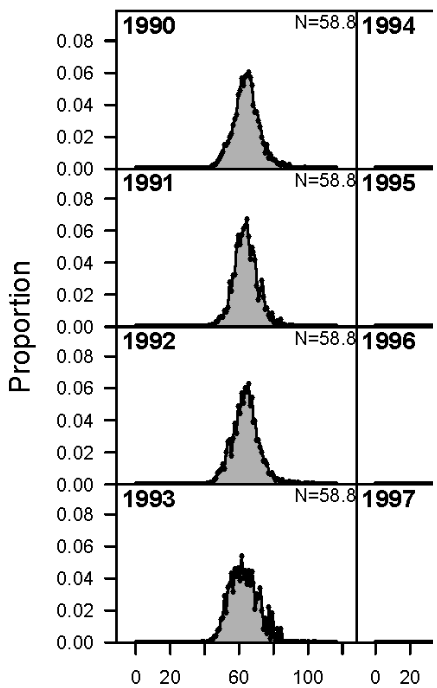
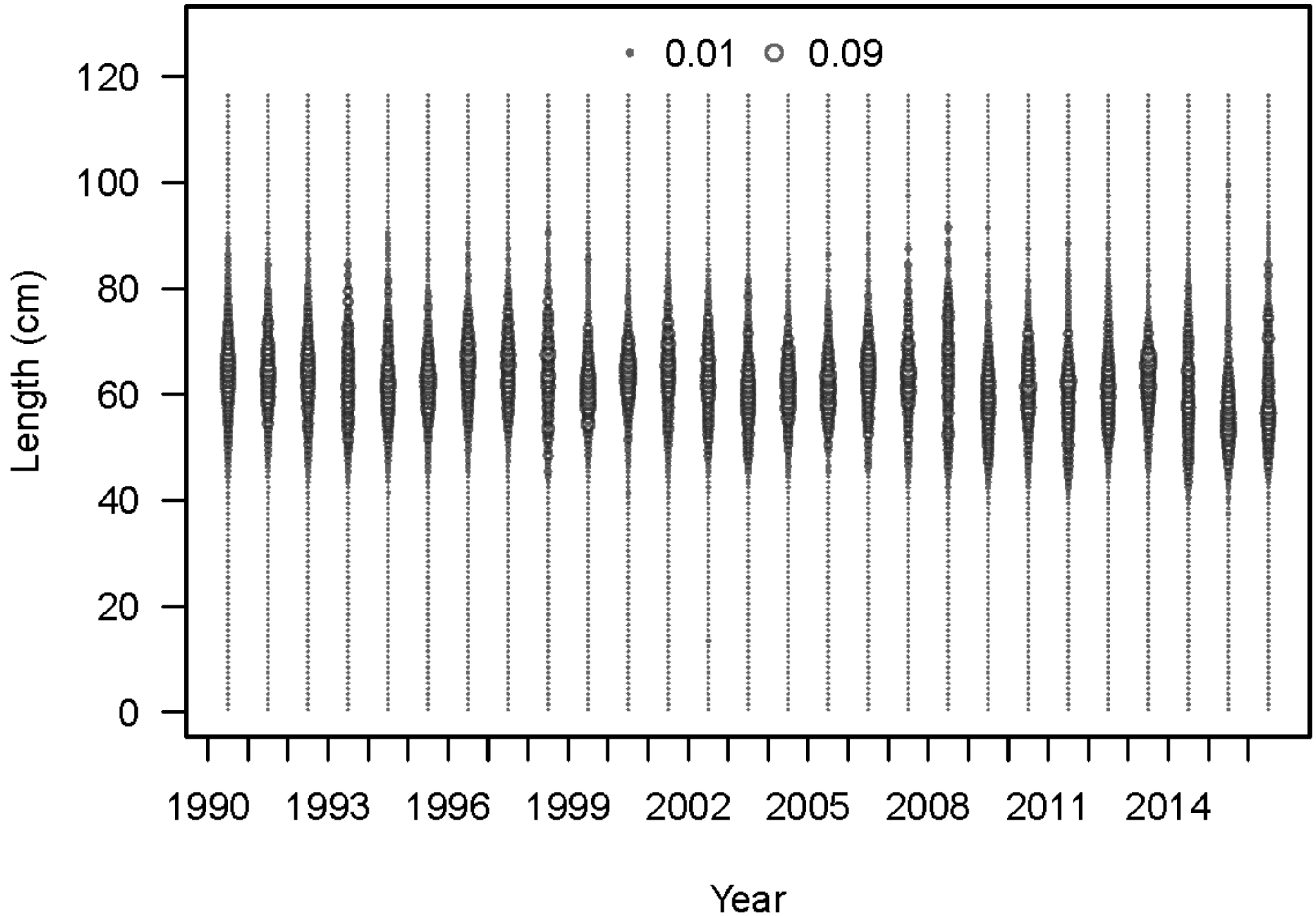
NMFS longline survey length composition data





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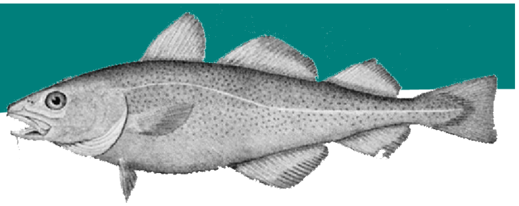
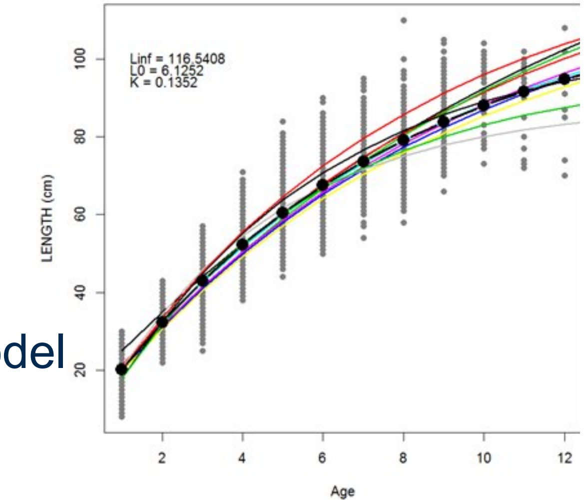


Base model: Stock Synthesis 3.24U

- Maturity
  - Function of age following Stark (2007) with **A_{50} at 4.3499 and slope of -1.9632**
- Natural Mortality
  - Jensen (1996) method **M = 0.38** based on A_{50} from Stark (2007)
- von Bertalanffy growth curve
  - Three parameter all uniform priors
    - $L_{0.5}$ initialized at 6.1252 cm
    - L_{inf} initialized at 116.541 cm
    - K initialized at 0.1352
- Weight at length fit log linear regression outside of model
  - A = 5.63096e-006
  - B = 3.1306



Base model

- Standard Beverton-Holt stock recruitment curve
  - Uniform prior on $Ln(R_0)$ bounded between 10 and 20
  - Steepness (H) fixed at 1.00
  - Sigma R fixed at 0.44 (fit in previous model runs)

- Recruitment deviations fit as simple deviations
  - Bounded between -5 and 5
  - Main recruitment deviations 1978-2013 fit in phase 1
  - Early recruitment deviations 1962-1977 fit in phase 2
  - Forecast recruitment deviations 2014-2016 fit in phase 7

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Base model

- Stock Synthesis Hybrid method for fishing mortality estimation
  - Initial Fs for trawl and longline fishery fit with uniform prior
  - Initial F for pot fishery fixed at 0 – no fishery until 1986

- NMFS bottom trawl survey catchability fixed at Q = 1.00

- NMFS longline survey catchability allowed to float.

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Base model - Selectivity

- All length composition fit with a six parameter double normal curve
  - All parameters fit with uniform priors

  - Trawl and longline fishery (3 parameters free each)
    - Forced asymptotic with two parameters controlling downward arm fixed
    - Parameter 5 set at -999, causing initial selectivity to be near 0

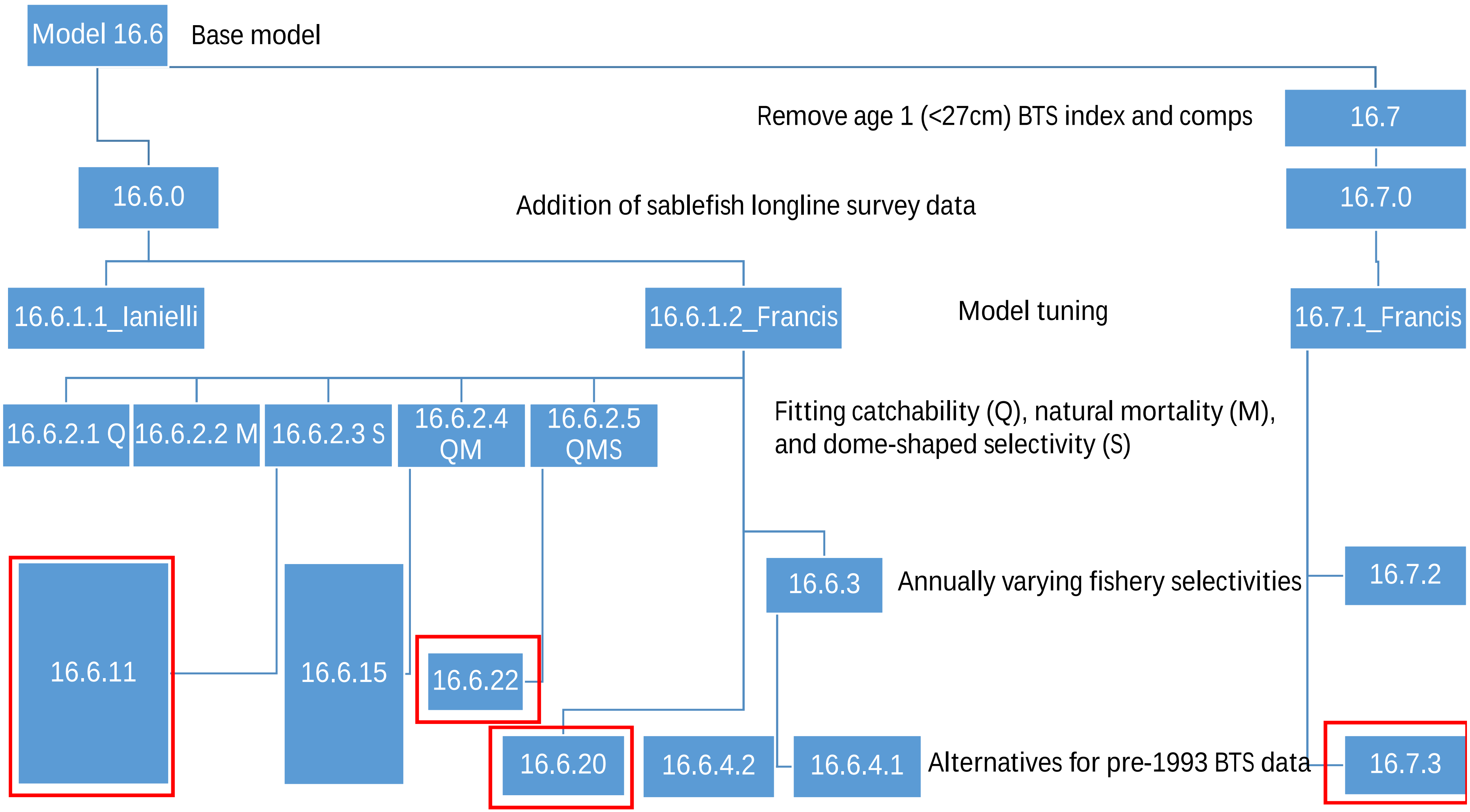
  - Pot fishery (5 parameters free)
    - Dome-shaped allowed
    - Parameter 5 set at -999, causing initial selectivity to be near 0

  - Bottom trawl survey (4 parameters free)
    - Forced asymptotic with two parameters controlling downward arm fixed

Base model - Other

- Initially ages were restricted to 12 ages with a 12+ group
- No aging error or bias
- Conditional length at age available in data, but not fit.

Models presented in September, 2016



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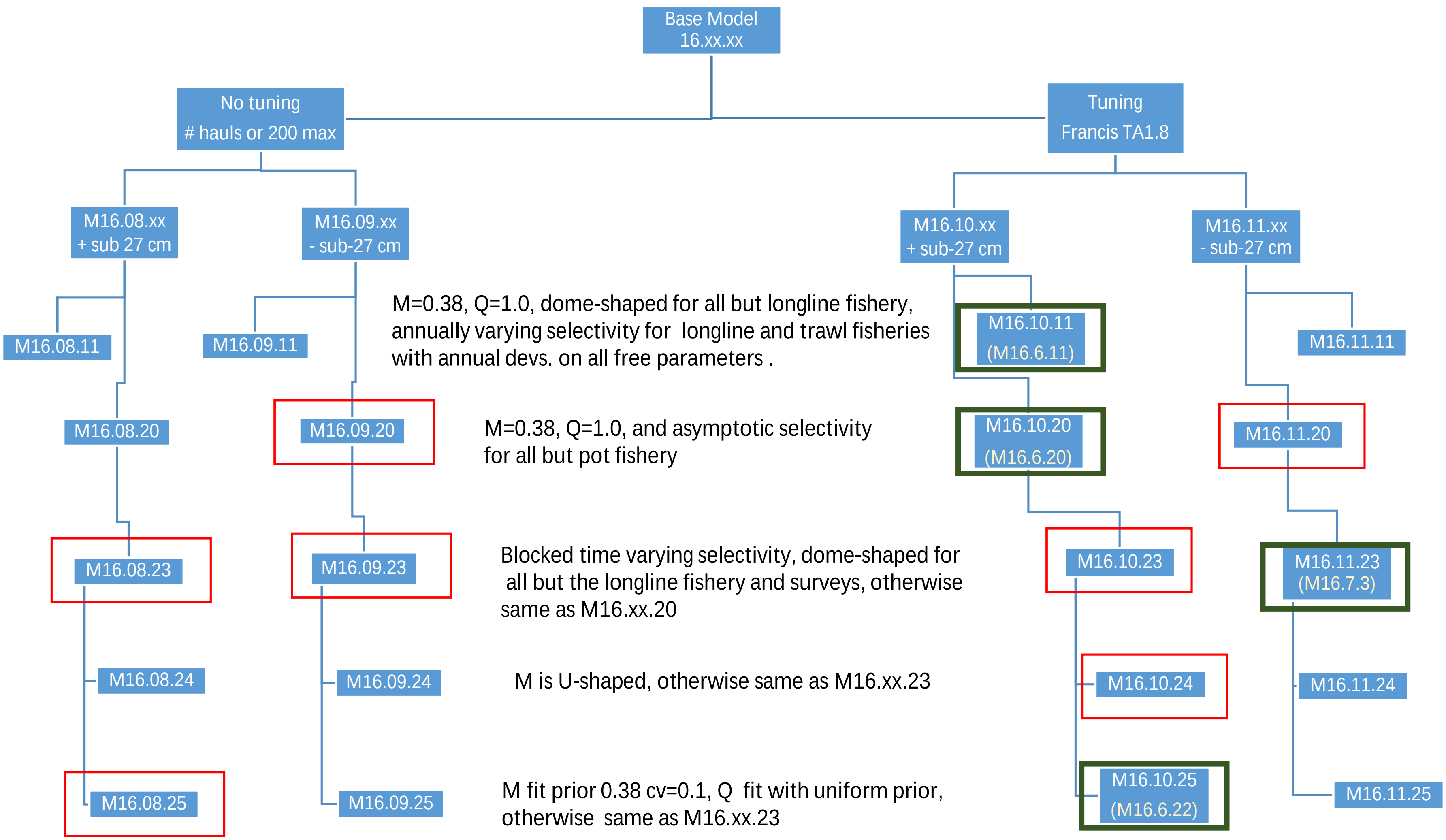
November base model differences from September

- Ages were restricted to 20 ages with a 20+ group
  - SSC addition
  - Small differences in fitting growth parameters
- Conditional age-at-length data from survey fit within model
  - More stable model fit for growth
- R_1 offset fit with uniform prior in phase 3
  - Best practices, adjusting R_1 from R_0 in fished population

Changes to base from September 2016 :
Addition of age-at-length, R_1 offset, and plus group at age 20+



Blocks for M16.xx.23 -M16.xx.25

Longline Fishery	1977-1995, 1996-2005, and 2006-2016
Trawl Fishery	1977-1995, 1996-2005, and 2006-2016
Pot Fishery	1977-2012 and 2013-2016
Bottom trawl survey	1977-1995, 1996-2006, 2007-2016

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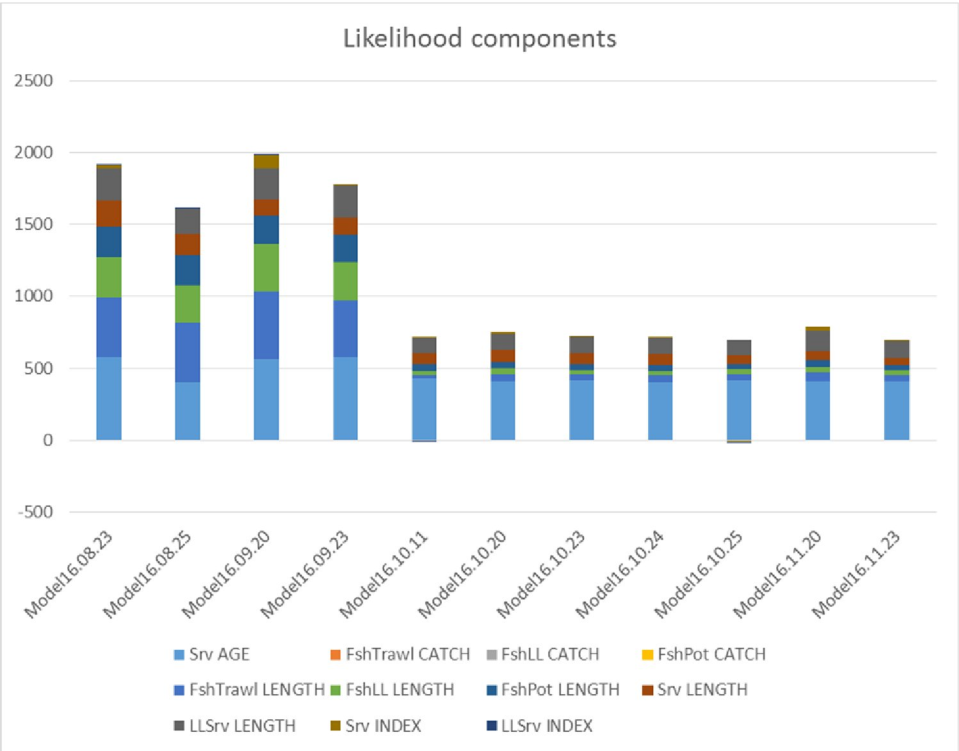
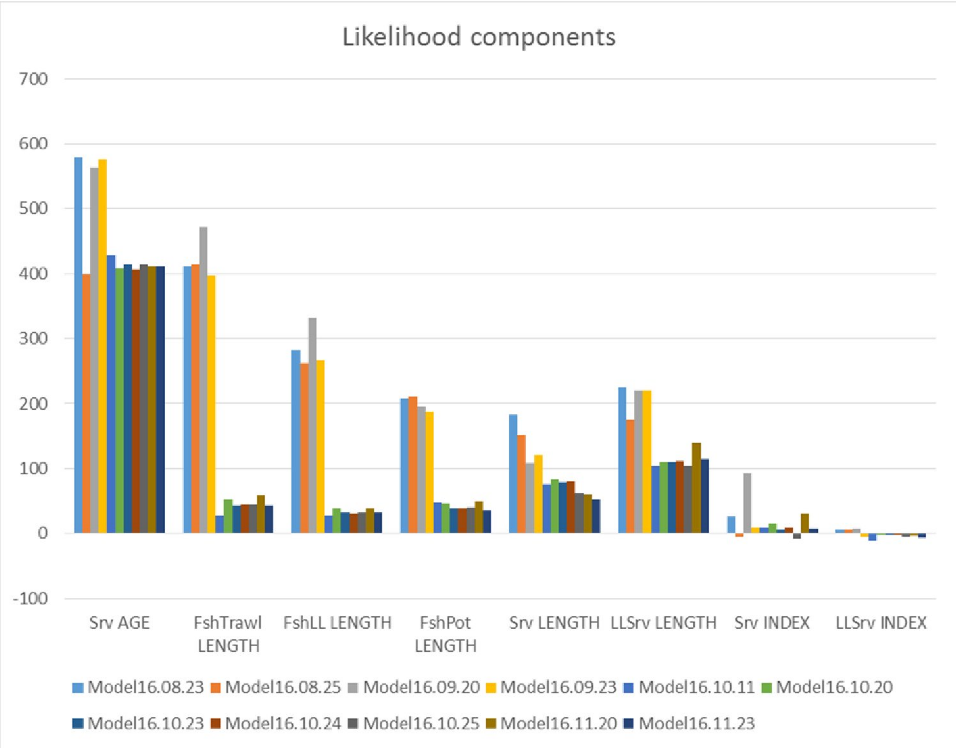
Model fits (Likelihoods)



- Likelihoods not comparable between series because of tuning and data differences



- Within series models 16.xx.25 best overall
- Some individual components fit less well

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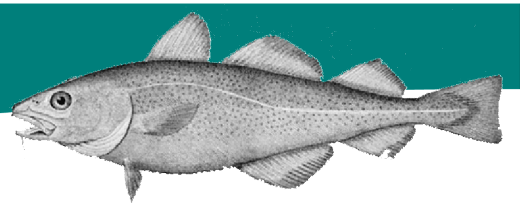
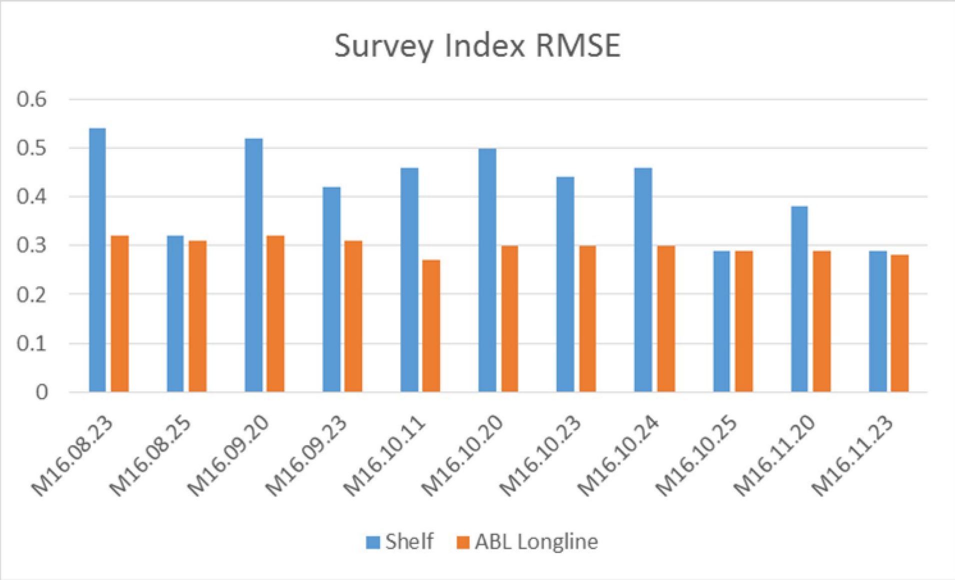
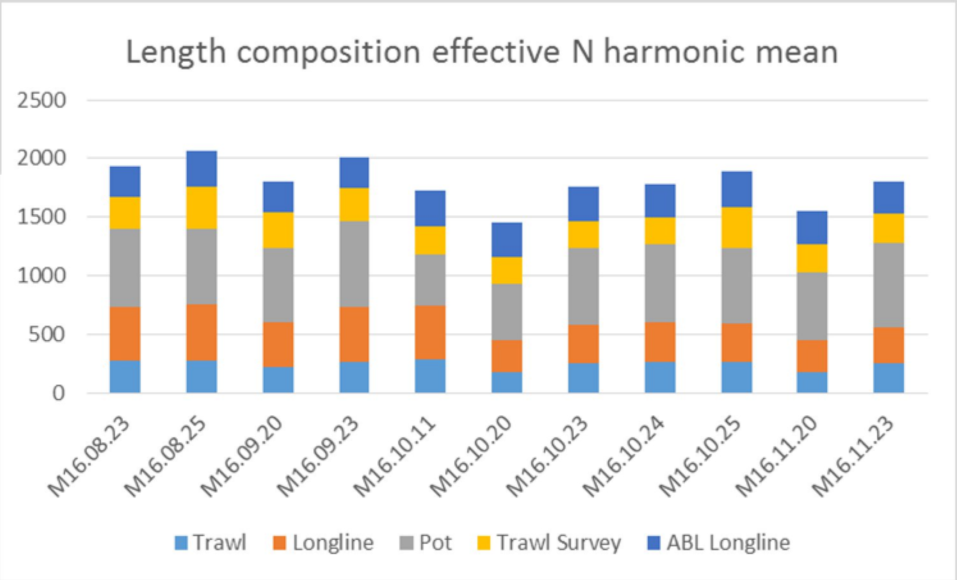


Model fits (RMSE and mean eff. N)



- Little difference in fits to longline survey
- Tuned models show better fit (lower RMSE) to NMFS Bottom trawl Survey



- Best fit (highest effective N) to length composition data in un-tuned models
- Model config. M16.xx.25 best fit overall within series

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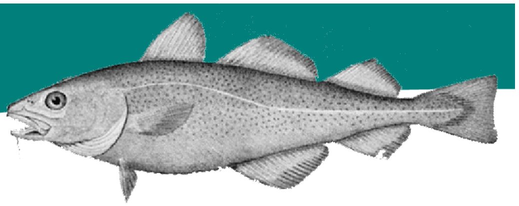
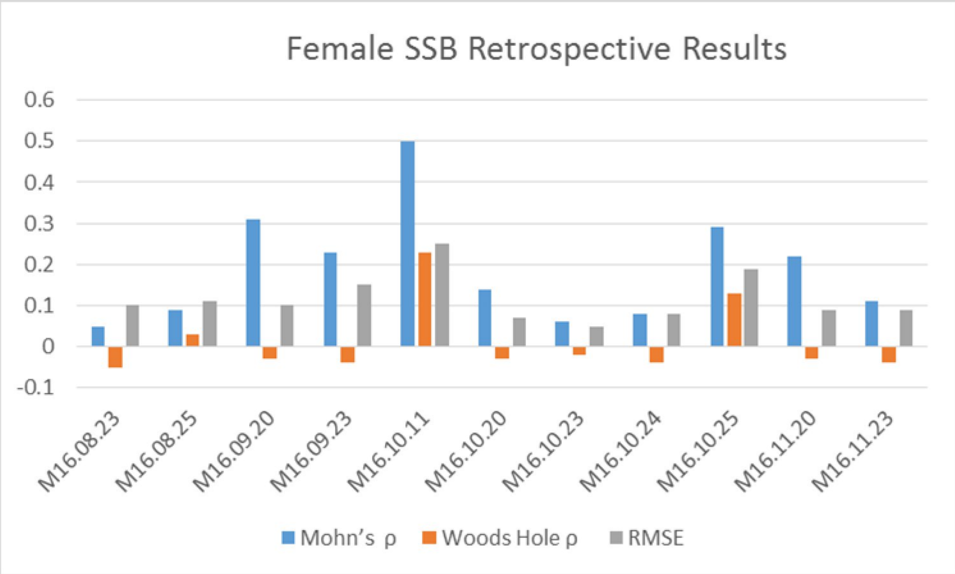
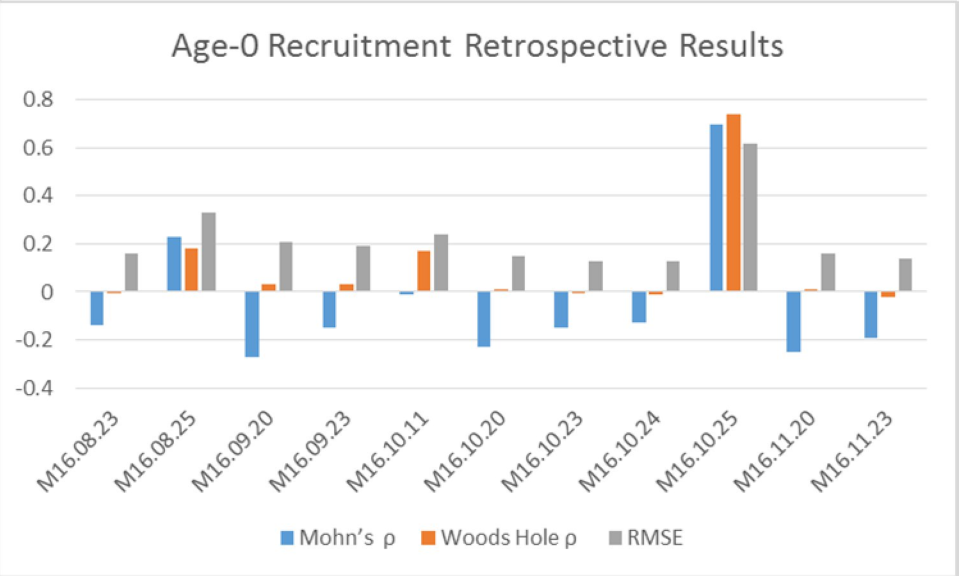


Retrospective results



- In general models with sub-27 cm better retrospective
- Model config. 16.xx.23 best retrospective within series

- Positive FSSB retrospective bias for all models in Mohn's ρ
- Poor retrospective patterns on Models 16.09.20, 16.09.23, 16.10.11, 16.10.20, 16.10.25, and 16.11.20



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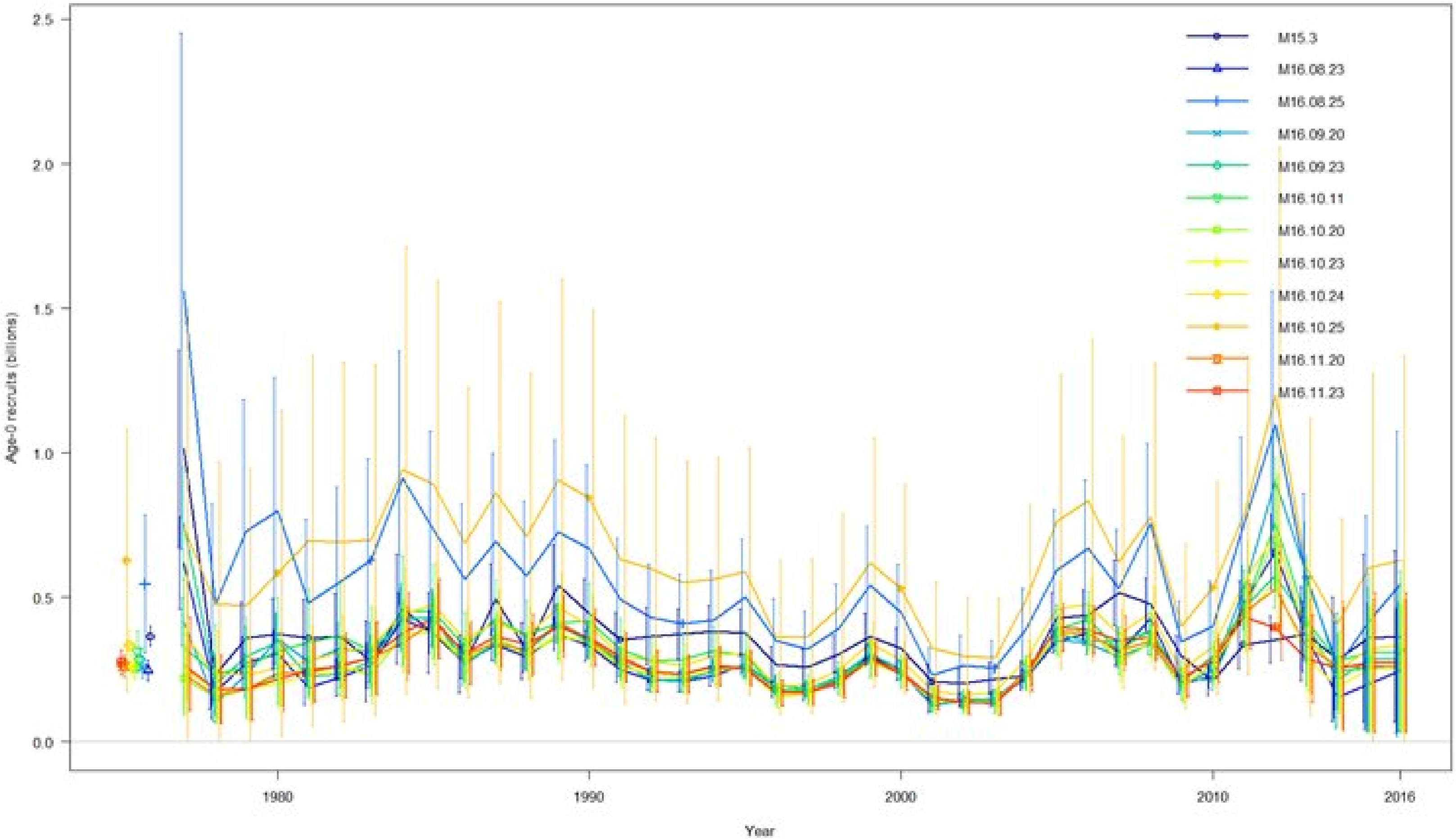
Age-0 recruitment comparisons



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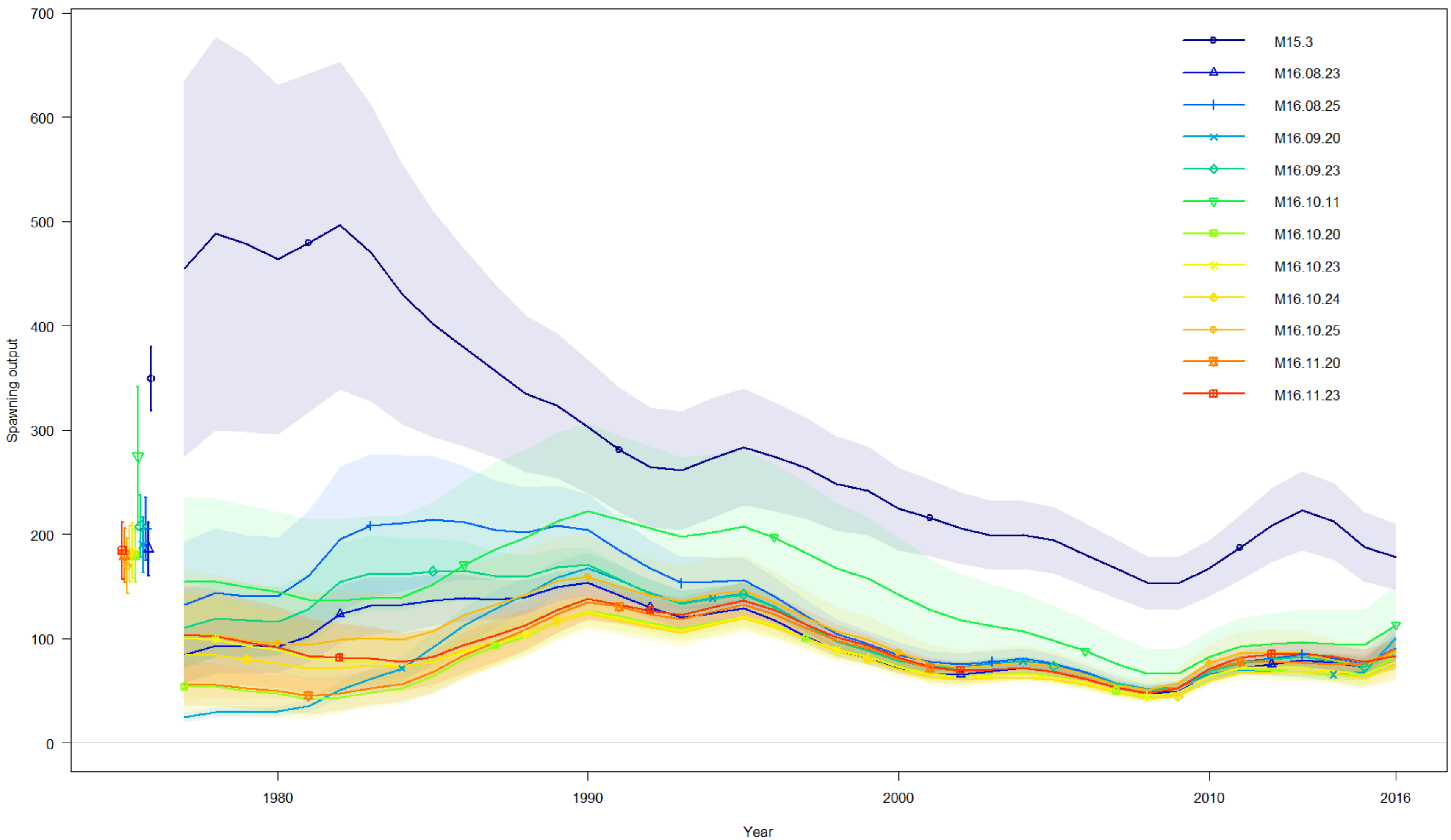
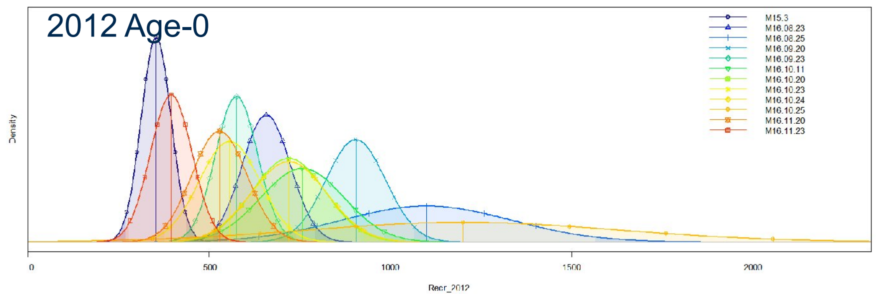
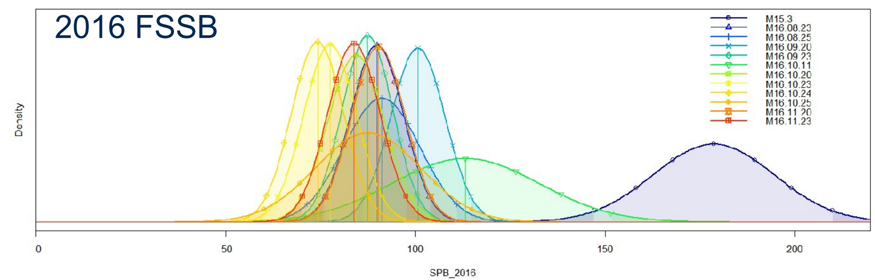
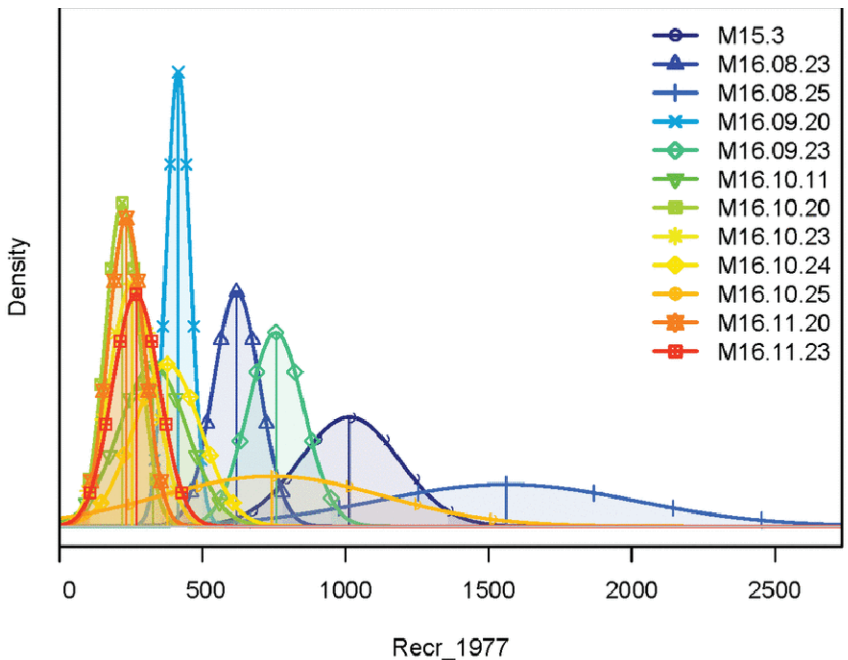
Spawning stock biomass comparisons

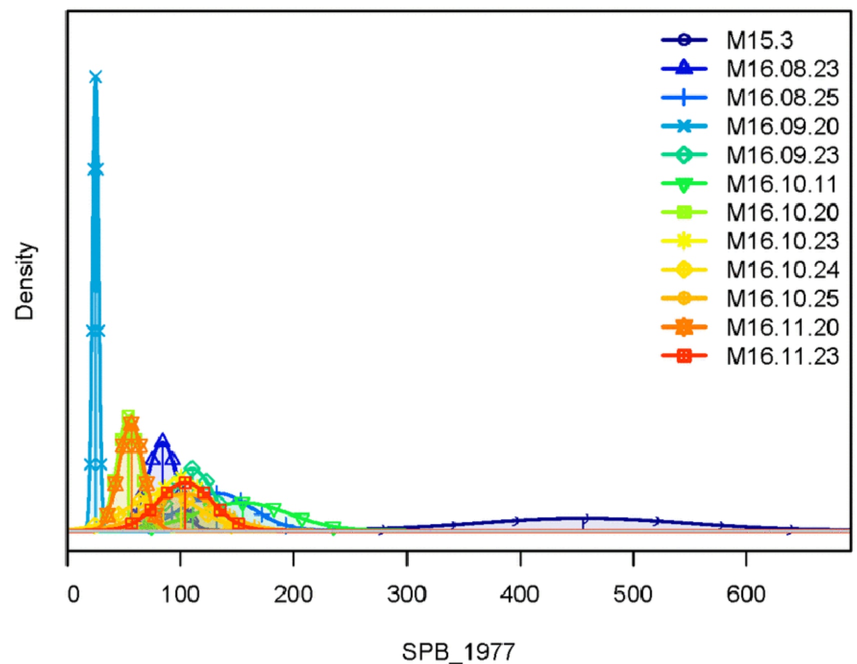


Spawning stock biomass and recruitment comparisons









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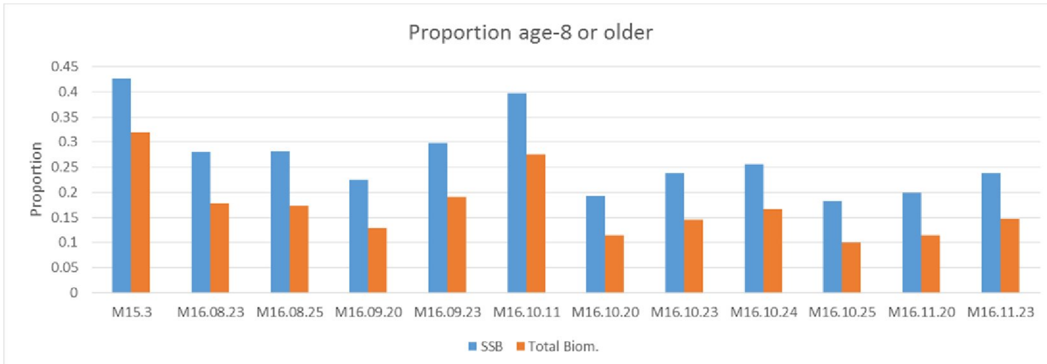
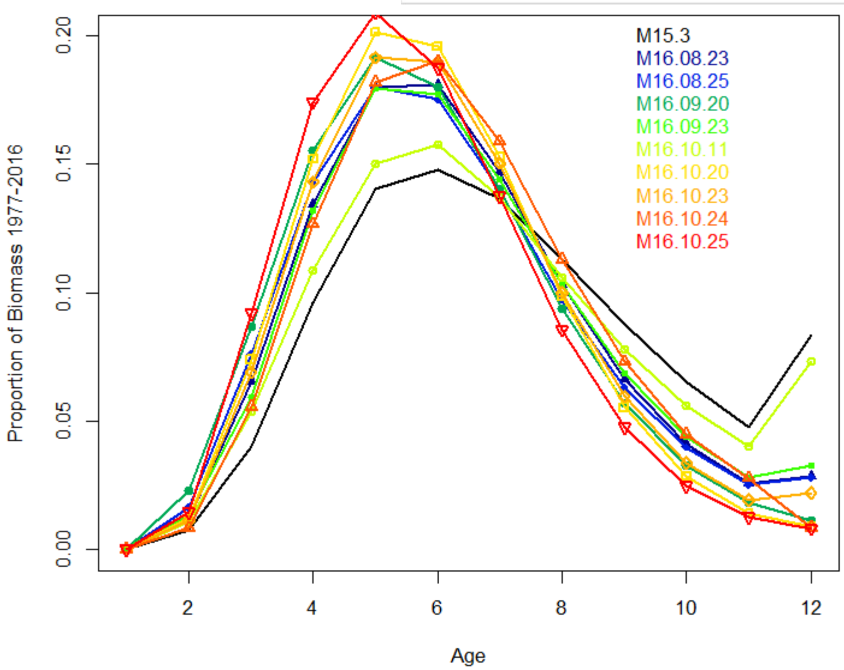
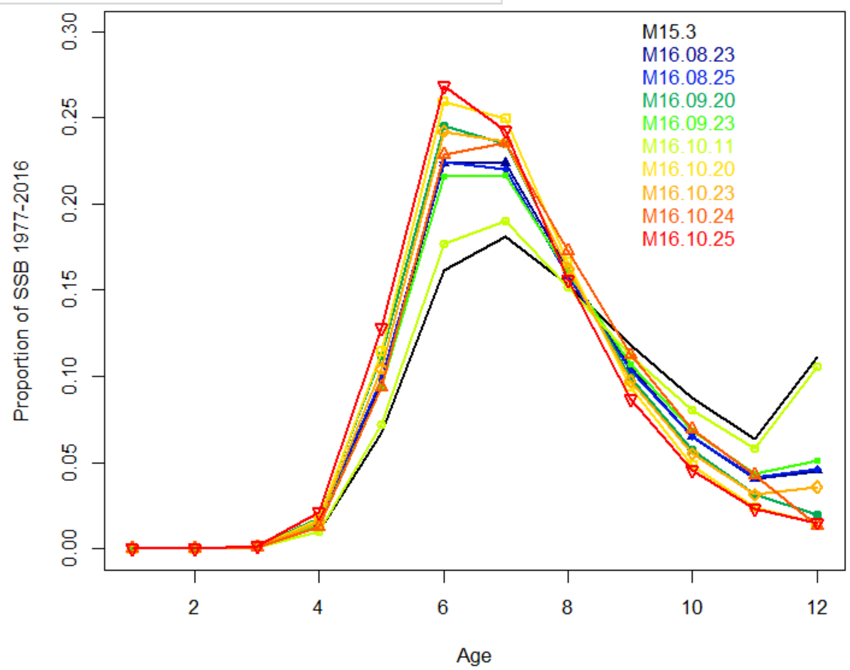
Biomass age distributions







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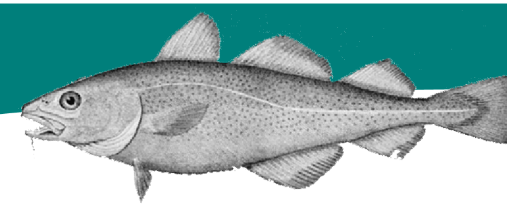
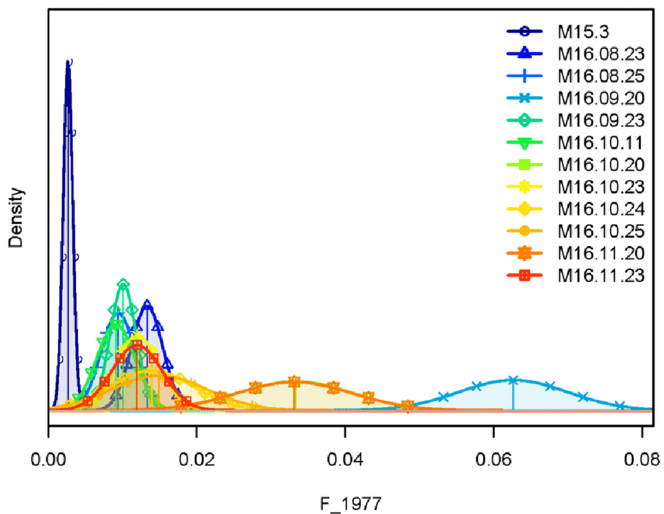
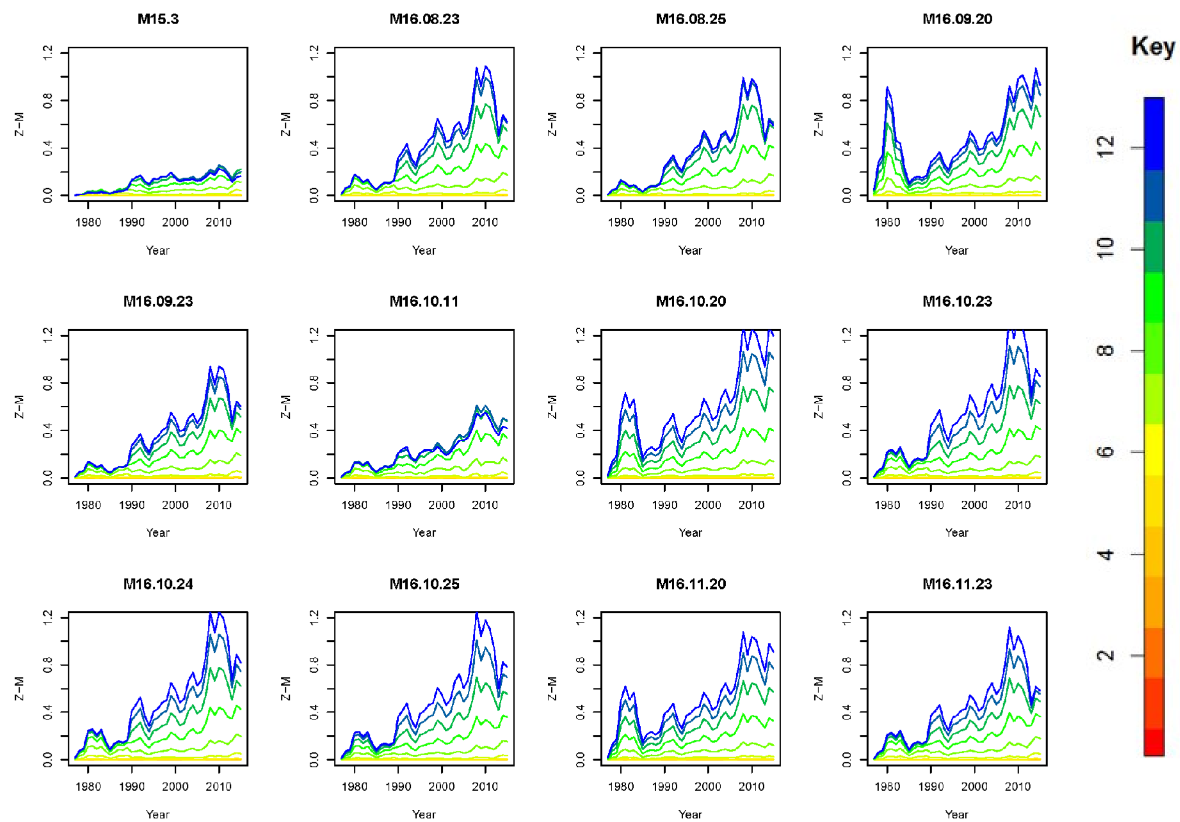


Fishing mortality and fishing mortality at age





Author’s choice: Model 16.08.25

- Best fit model overall (AIC)
- Model well behaved,
  - Jitters always converged at minimums
  - Reasonable retrospectives
- Good characterization of population distribution at age (small cryptic component)
- Population trend mimics anecdotal history (gadid outburst in the early 1980s)
- Reference points and biomass estimates near the middle of models explored

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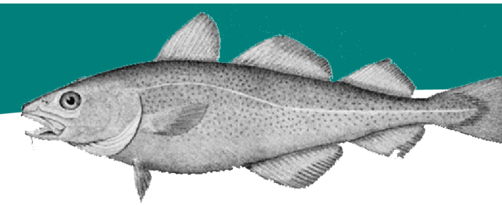

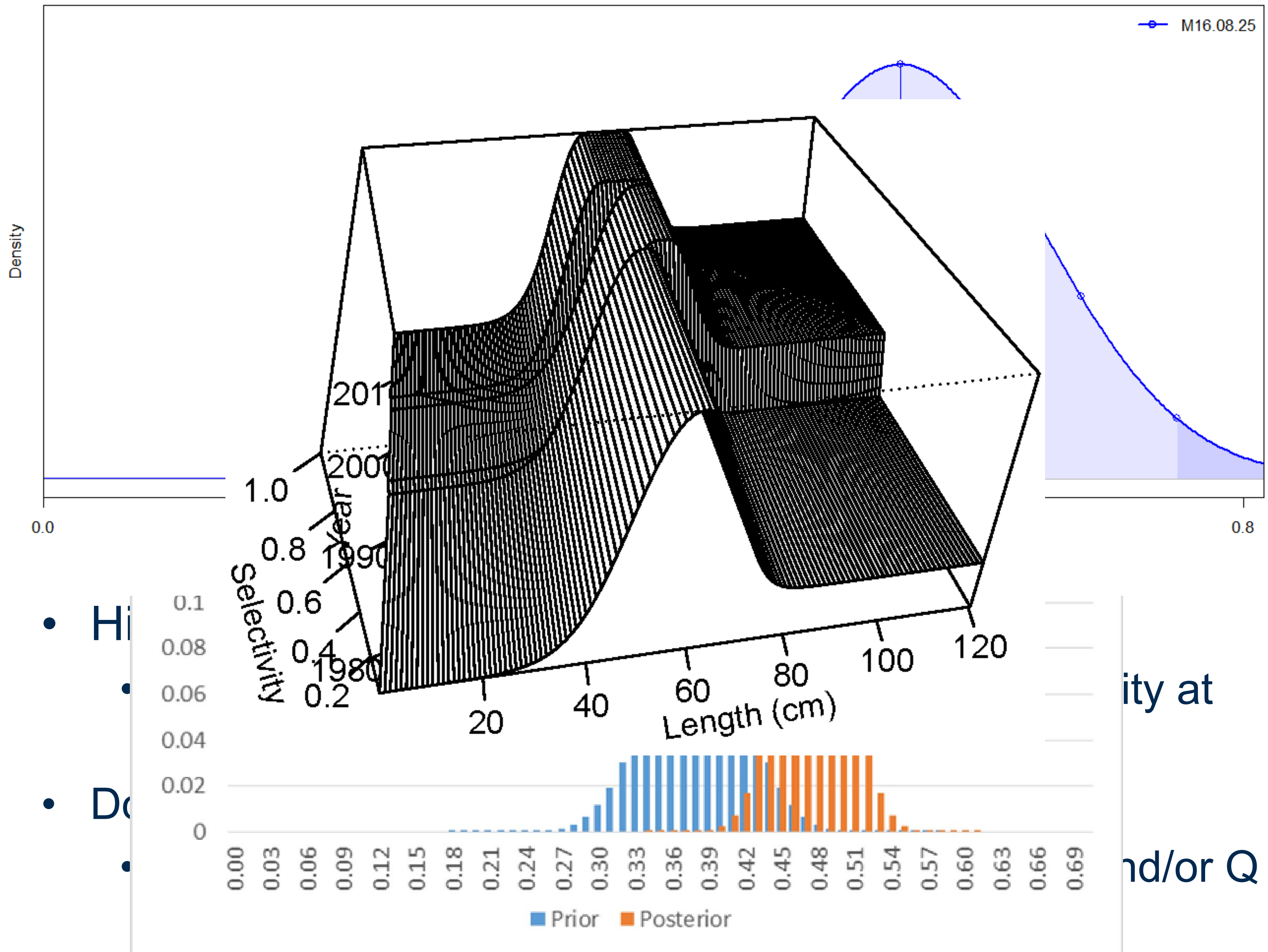

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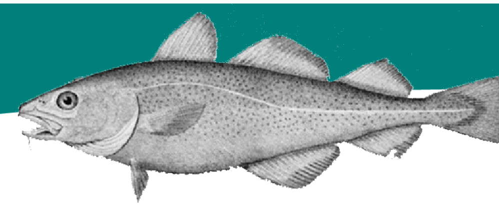
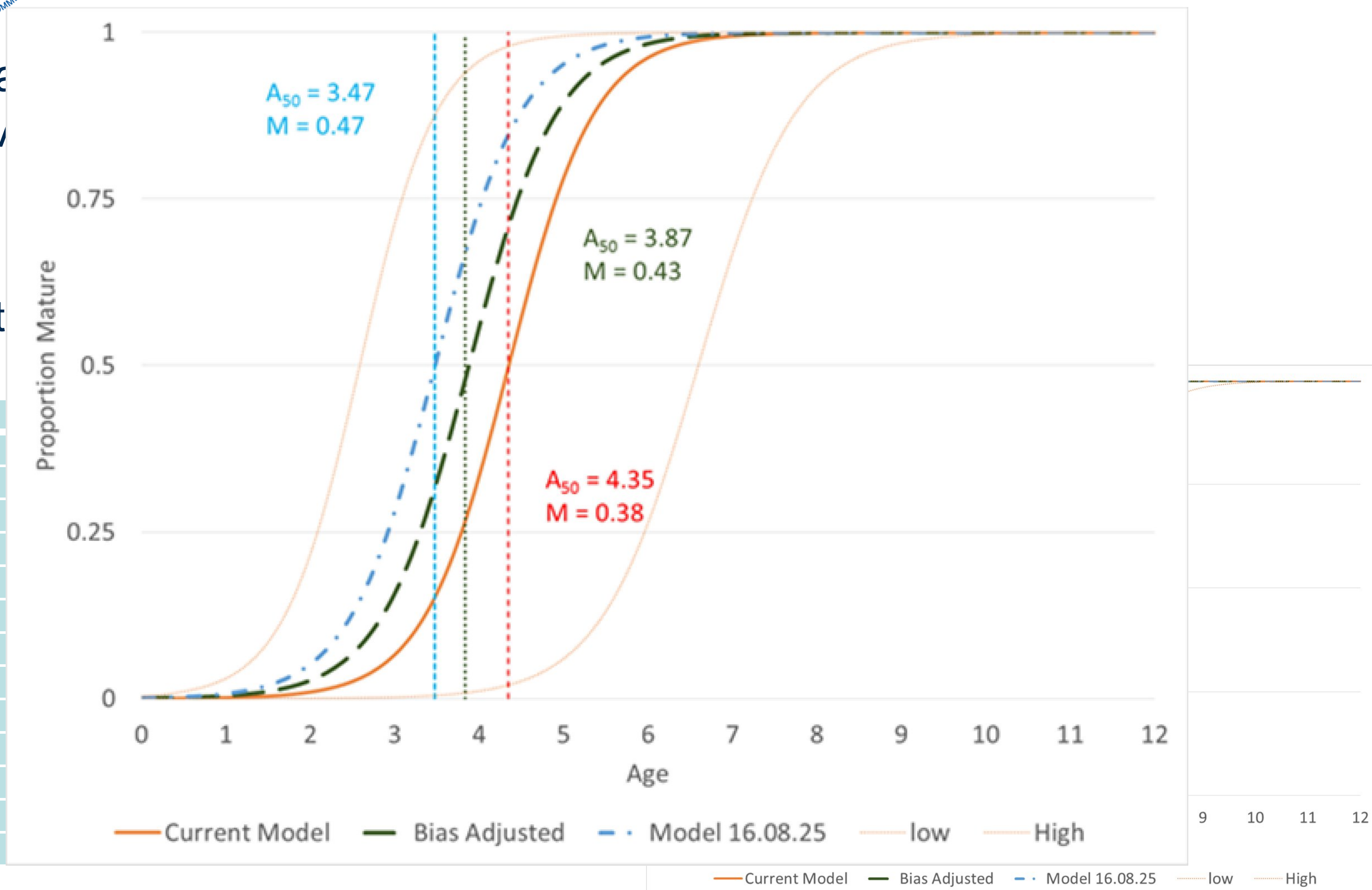


Justification for natural mortality at 0.47

- Estima
  howev

- Aging
  maturit

Area
Eastern Bering Sea
Eastern Bering Sea
Eastern Bering Sea
Eastern Bering Sea
Eastern Bering Sea
Eastern Bering Sea
Eastern Bering Sea
Gulf of Alaska
Gulf of Alaska
British Columbia
British Columbia
Korea
Japan

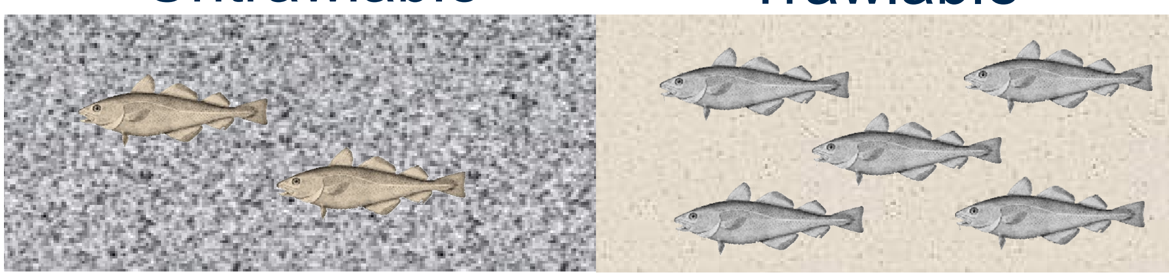


Possible reasons for Q > 1.0

- Q is a combination of gear efficiency and species availability at the highest selected length classes

- Differential distribution in trawlable vs. untrawlable habitat for these length classes could result in Q > 1.0

Untrawlable Trawlable



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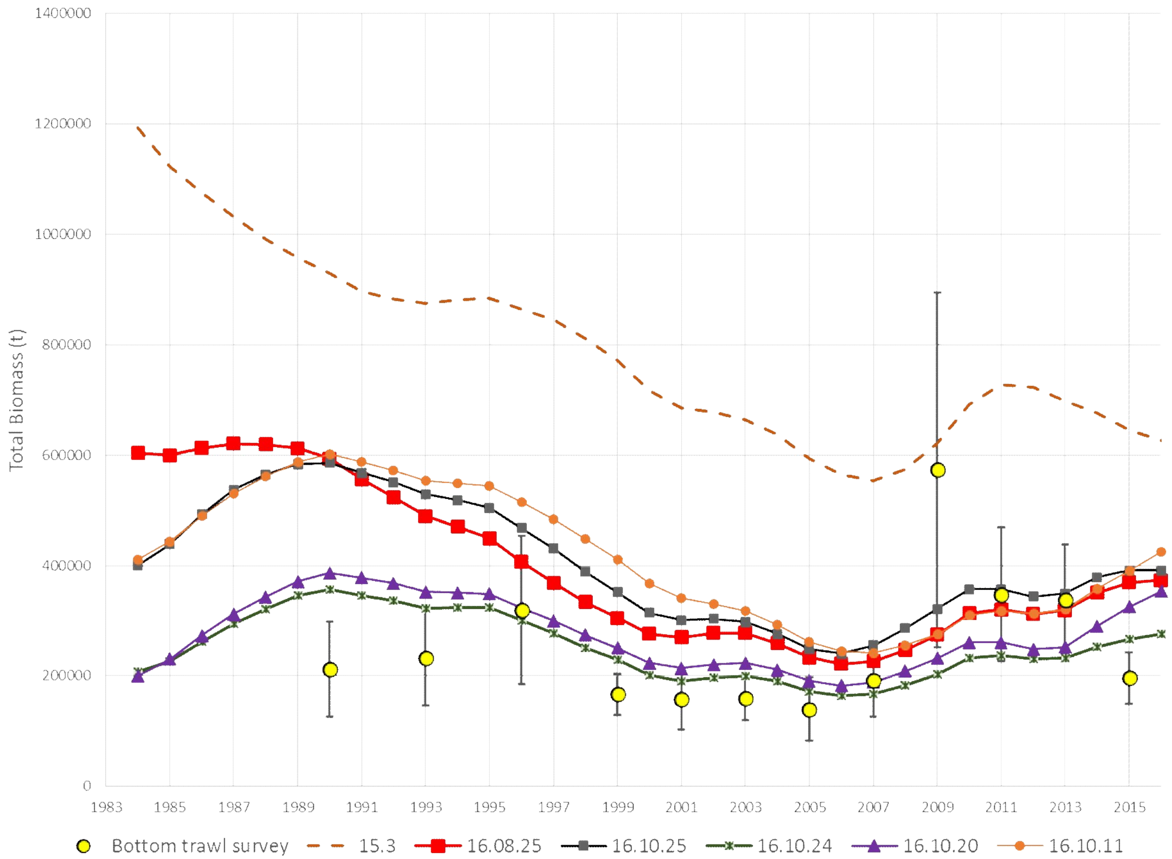
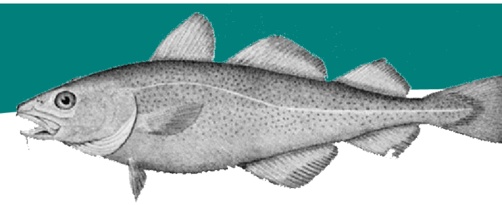
Model 16.08.25 catchability and selectivity

- Mean catchability × survey selectivity across length classes ≥ 27 cm = 0.94
- 1990-2015 average total biomass 154% NMFS BTS estimates
- Model 15.3 was 330%





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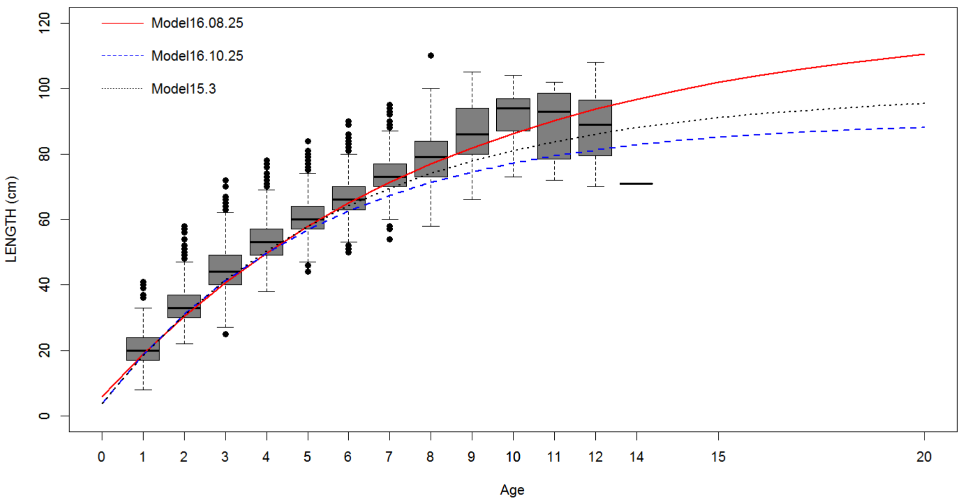
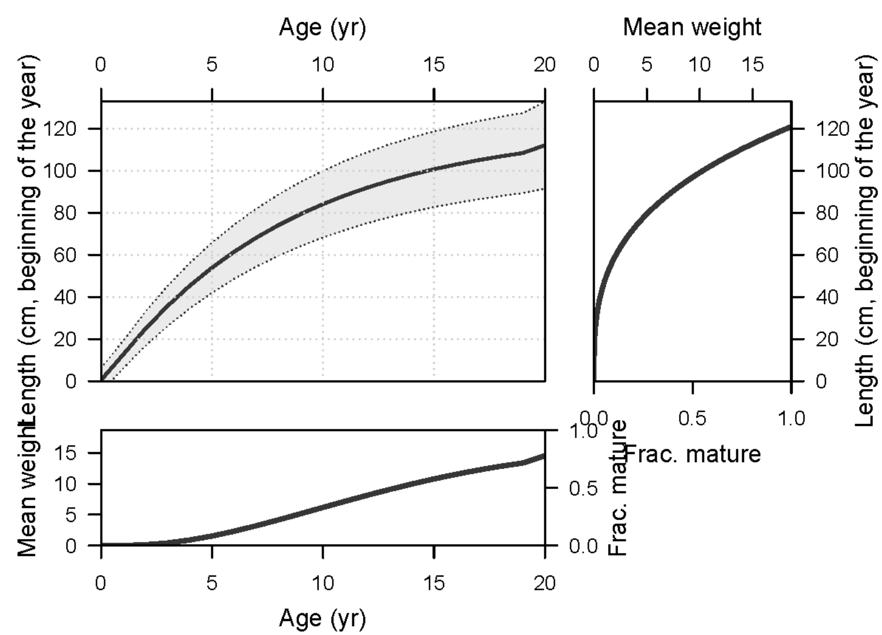
Model 16.08.25 growth

Von Bertalanffy fits to all EBS trawl survey age data



- Faster growth than Model 15.3
- Larger at older ages



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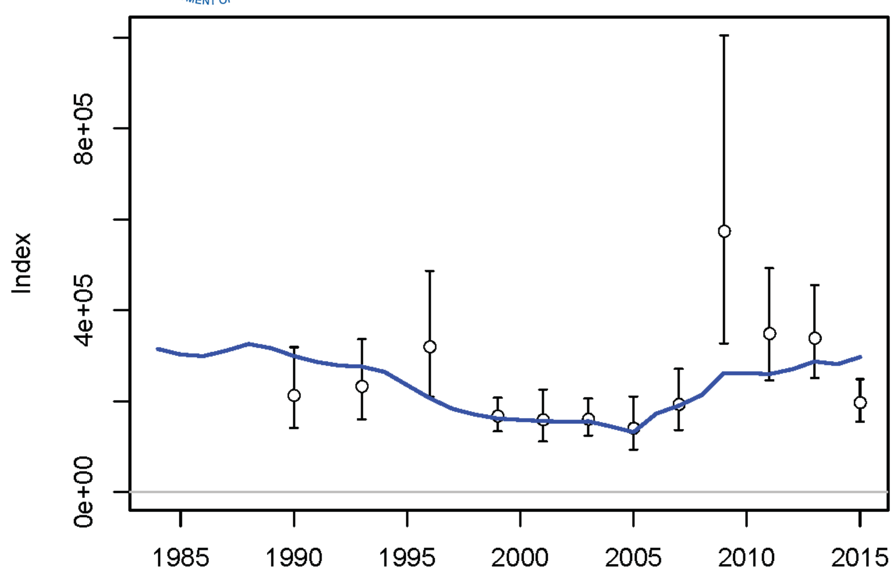
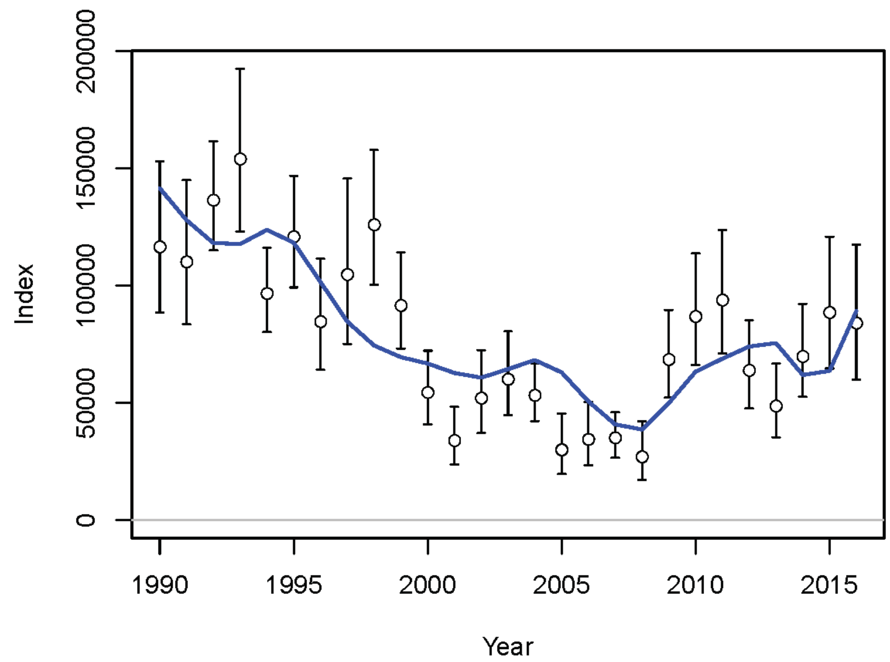
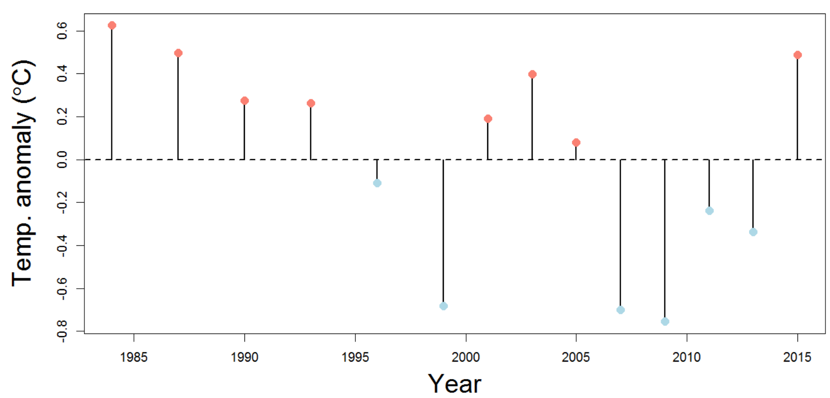
Model 16.08.25 fits: Indices







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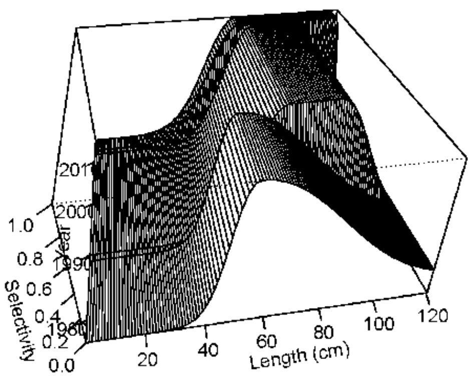
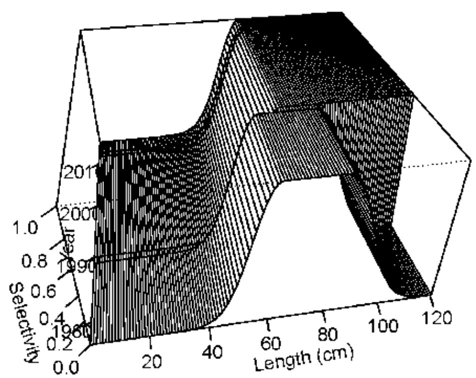
Selectivity

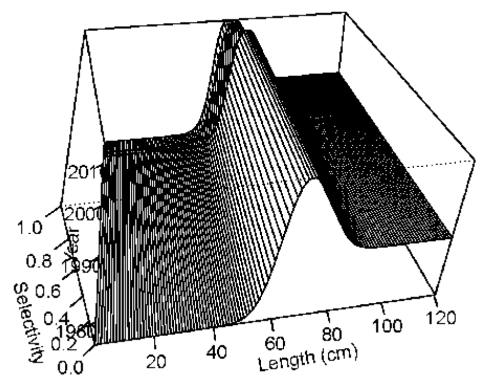
Time-varying selectivity for FshTrawl



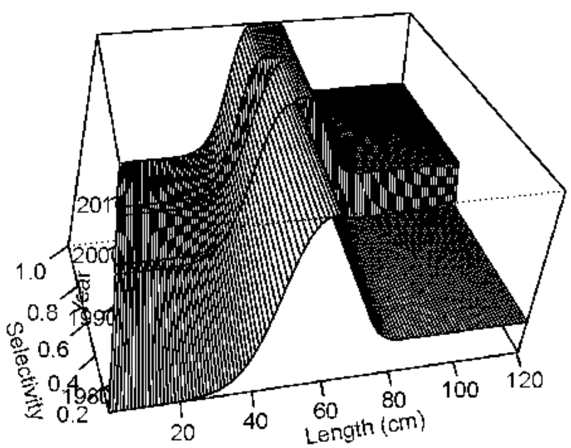
Time-varying selectivity for FshLL



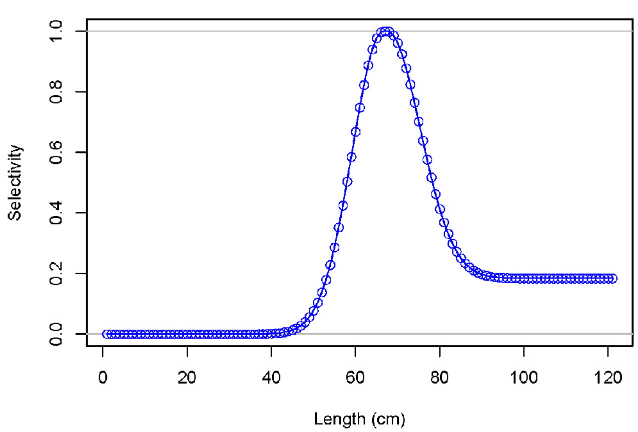
Time-varying selectivity for FshPot



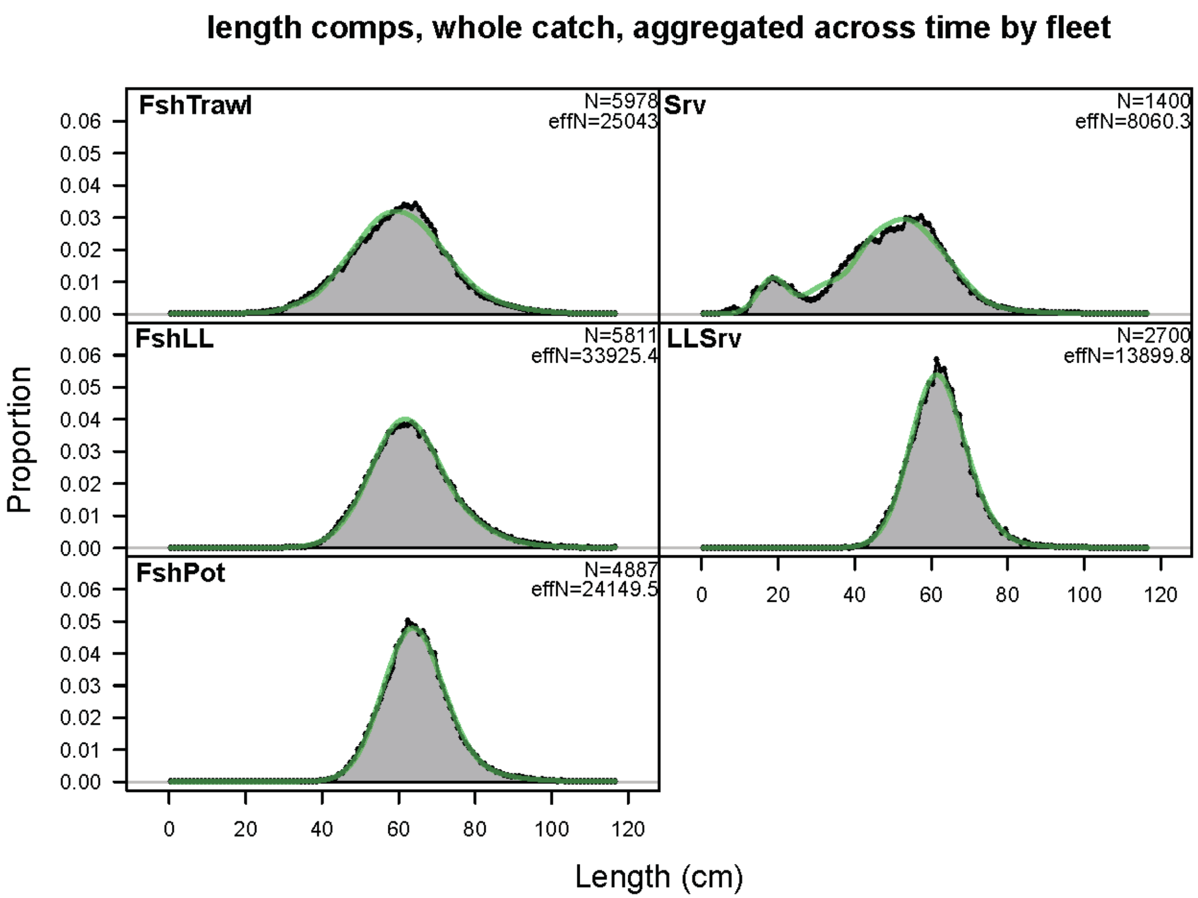
Time-varying selectivity for Srv



Ending year selectivity for LLSrv



Model 16.08.25 fits: Length composition



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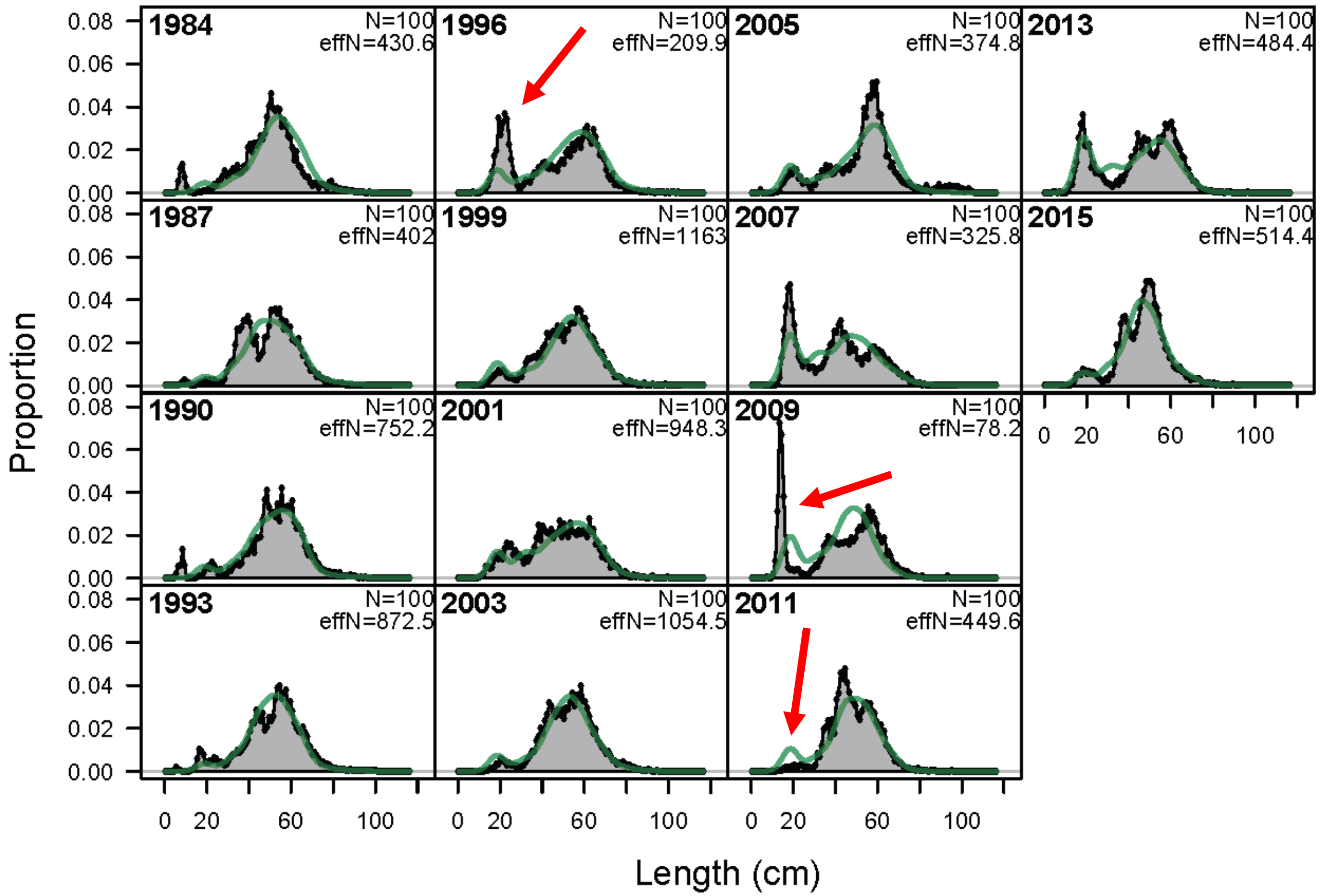
Model 16.08.25 fit: Bottom trawl survey length composition



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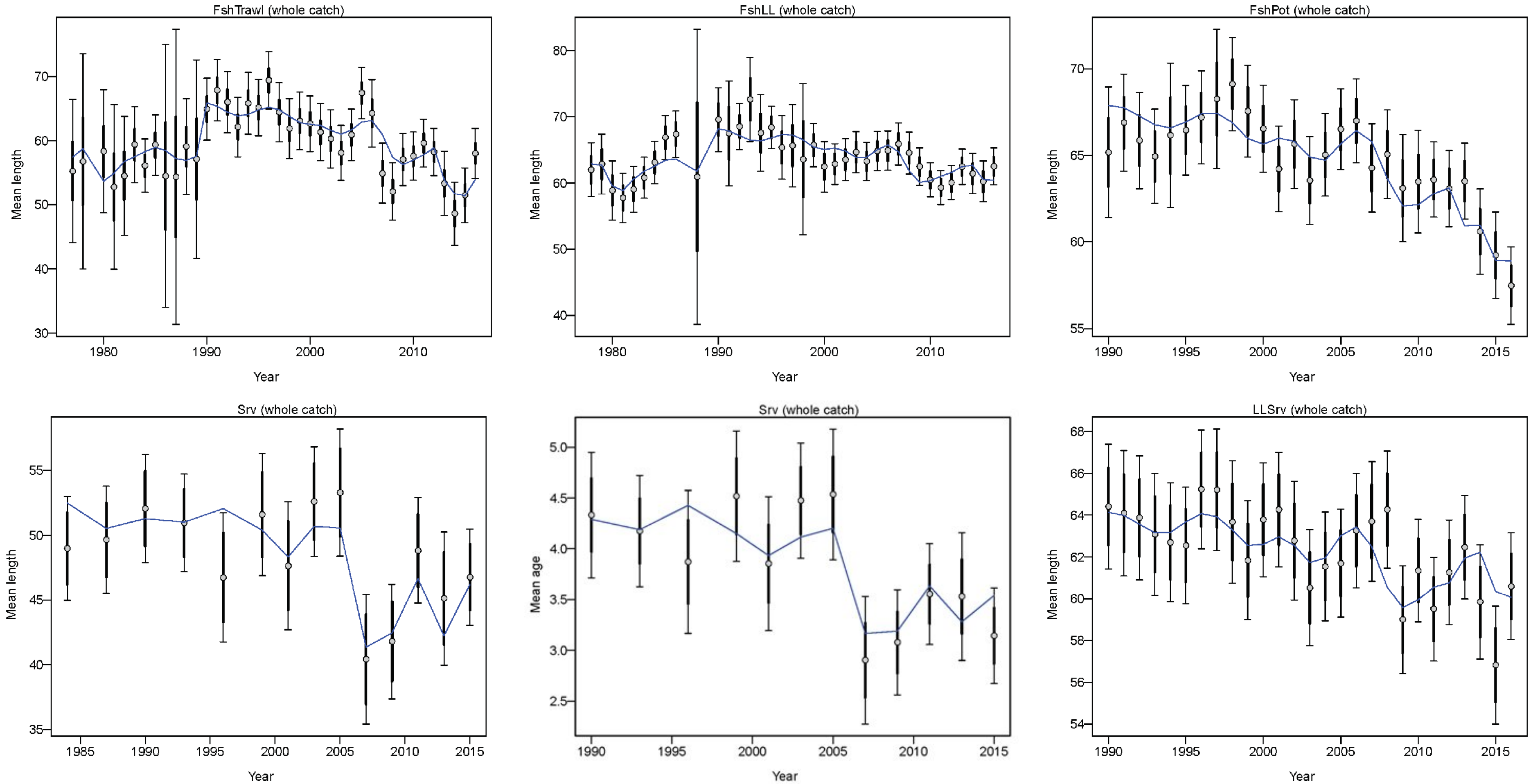
Model 16.08.25 fits: Mean length and age



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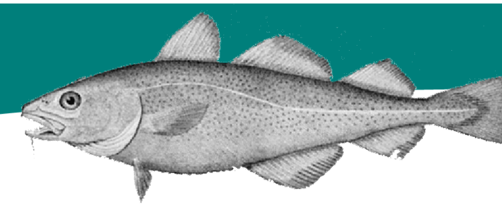
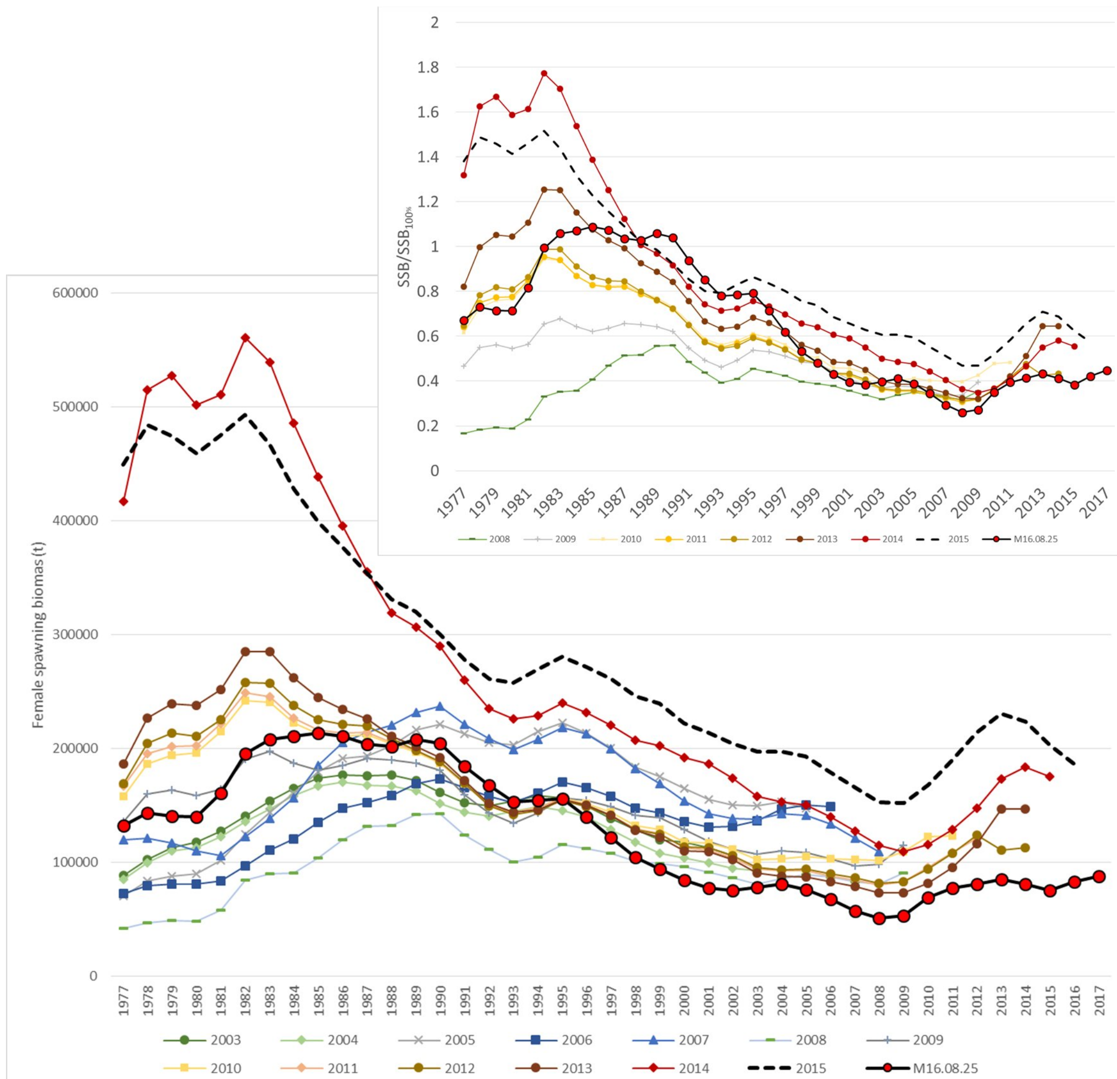


Model 16.08.25 results: Spawning biomass

- Near middle of historical estimates
- Lower spawning biomass overall in more recent estimates
- Current status lower than recent assessments ($\sim B_{40\%}$ for 2016)



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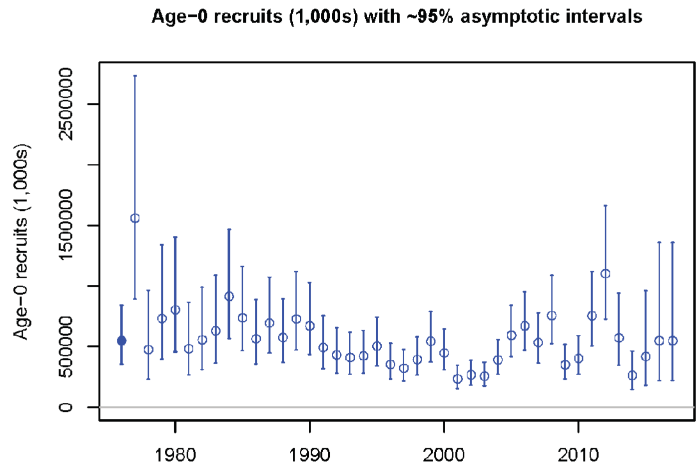
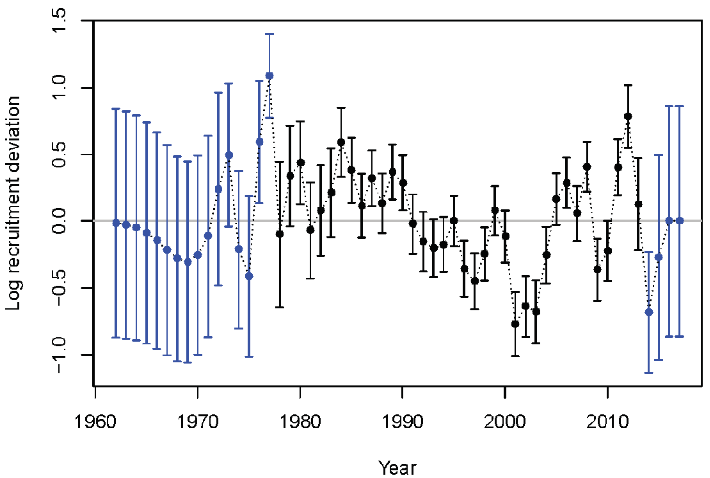
Model 16.08.25 results: Recruitment

- 1977 year class highest on record
- Poor recruitment 1990-2004
- Good 2005-2008 year classes
- 2009 -2010 poor recruitment
- 2012 year class 2nd highest on record
- 2014-2015 poor recruitment





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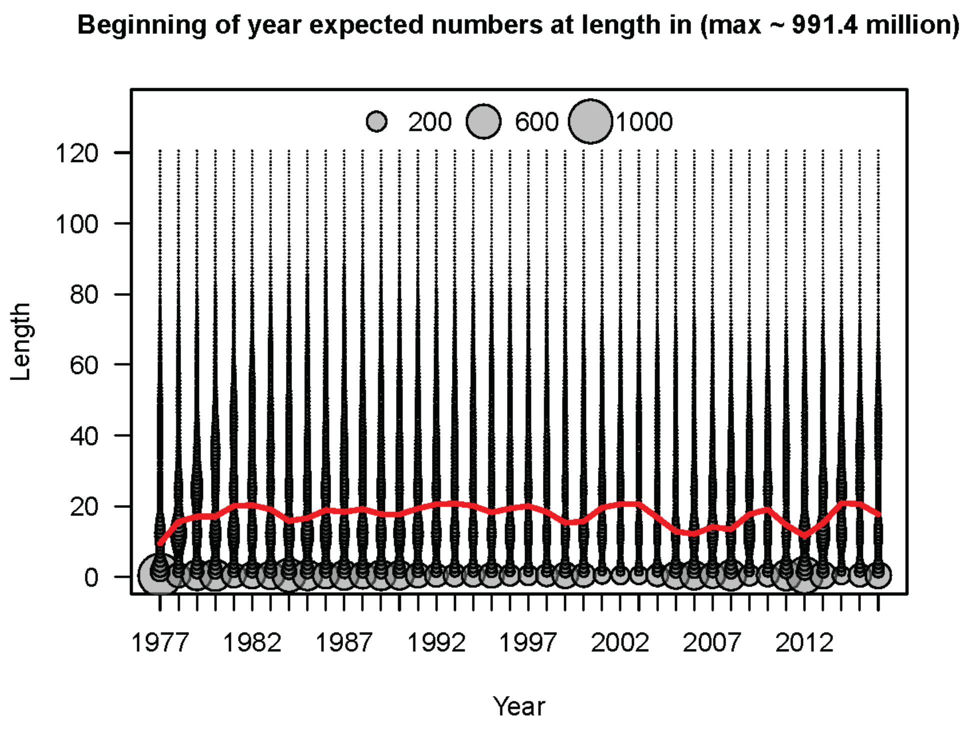
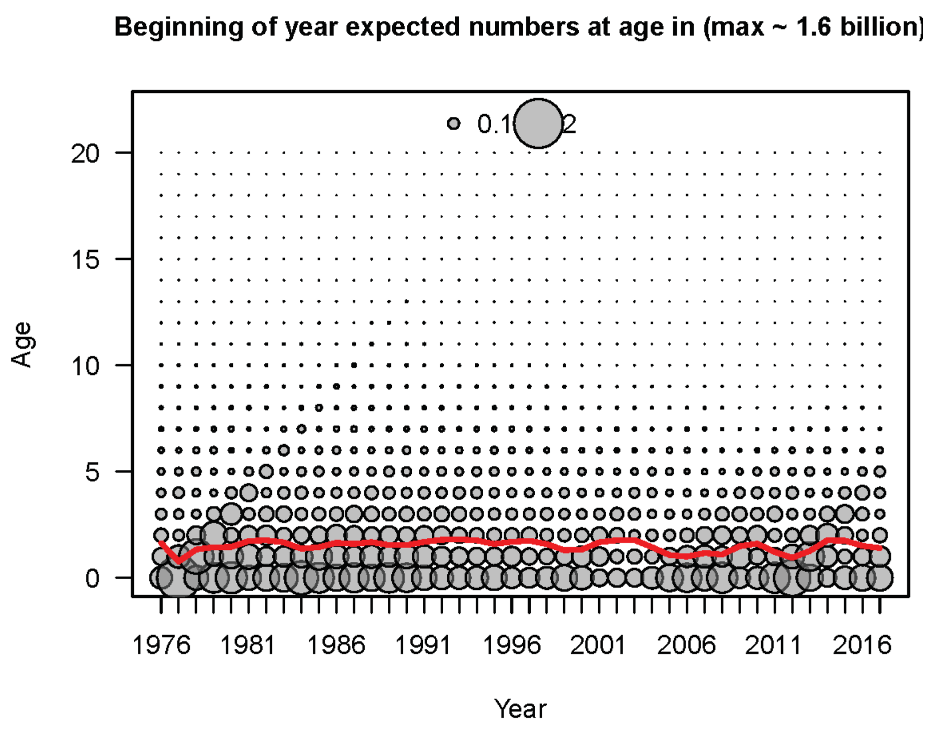
Model 16.08.25 results: Numbers at length and age





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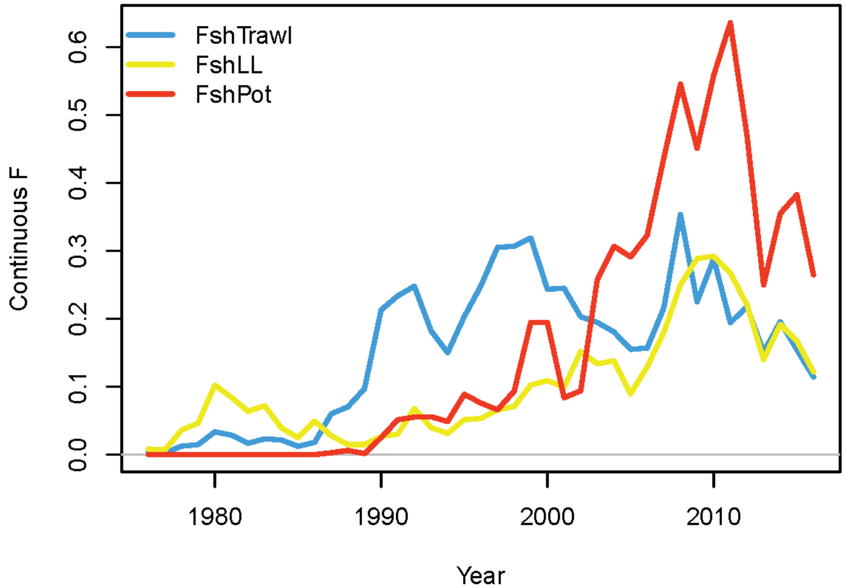
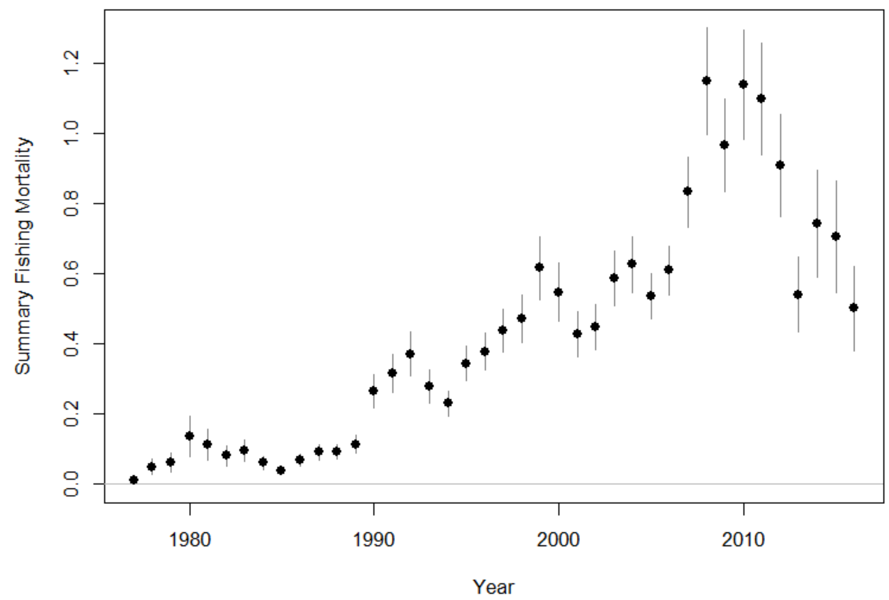
Model 16.08.25 results: Fishing mortality

- Low recruitment period was coincident with higher catches
- Model suggest fishing mortality in 2007-2012 was high and unsustainable





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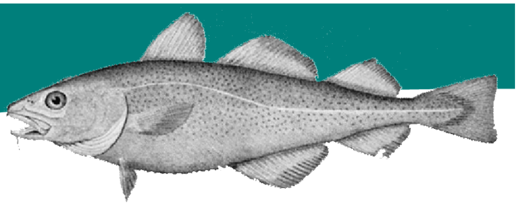
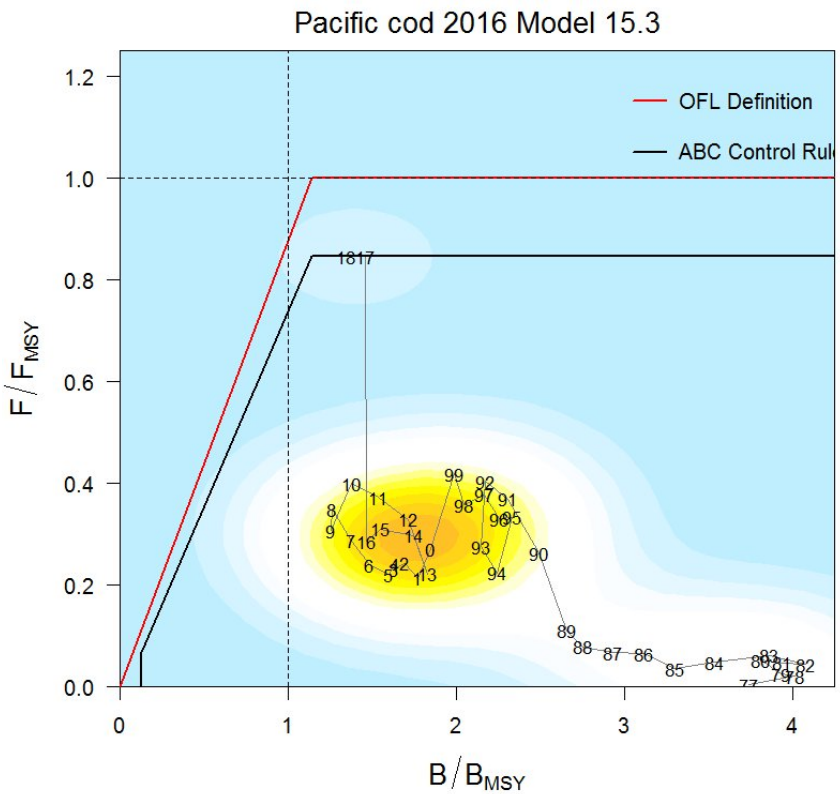
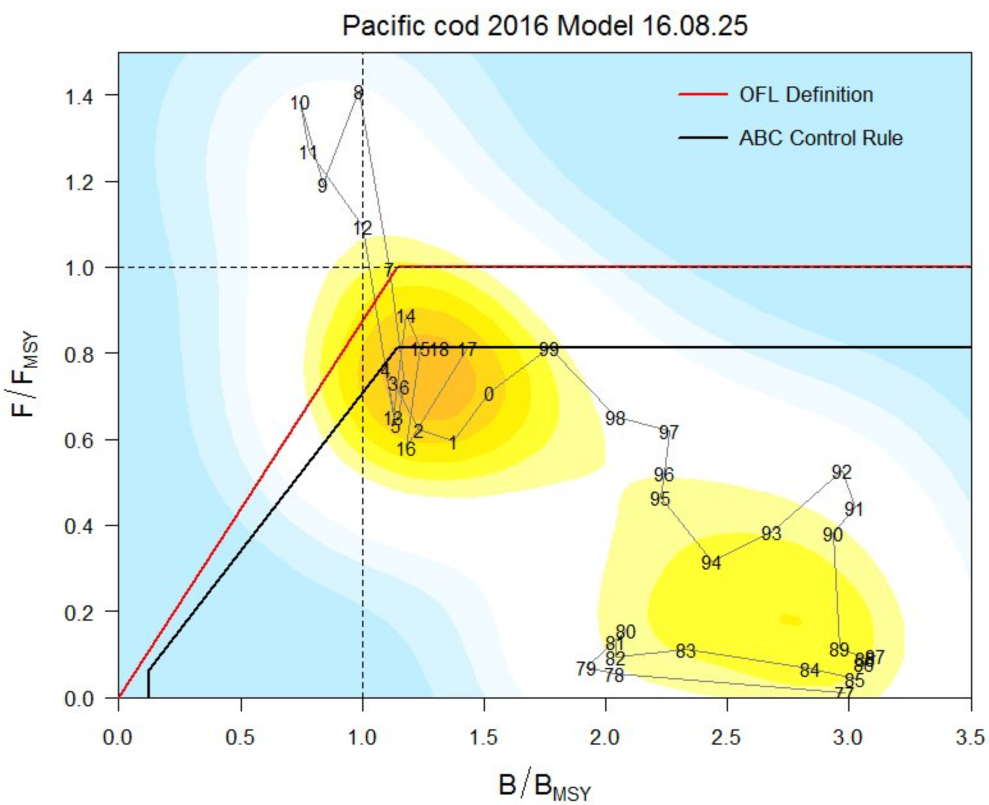


Model 16.08.25 results: Phase plane

- Status differs substantially from last year's Model 15.3





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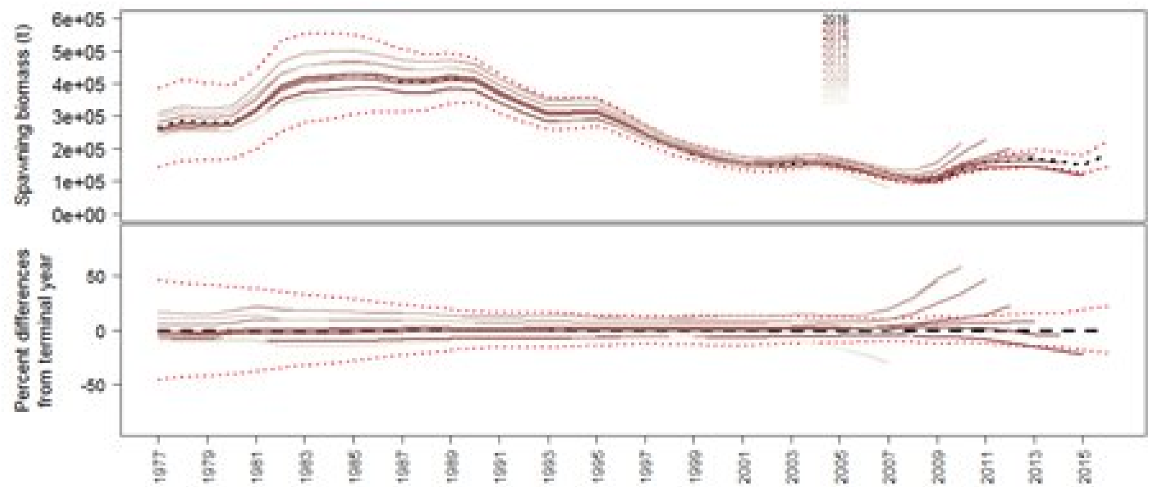
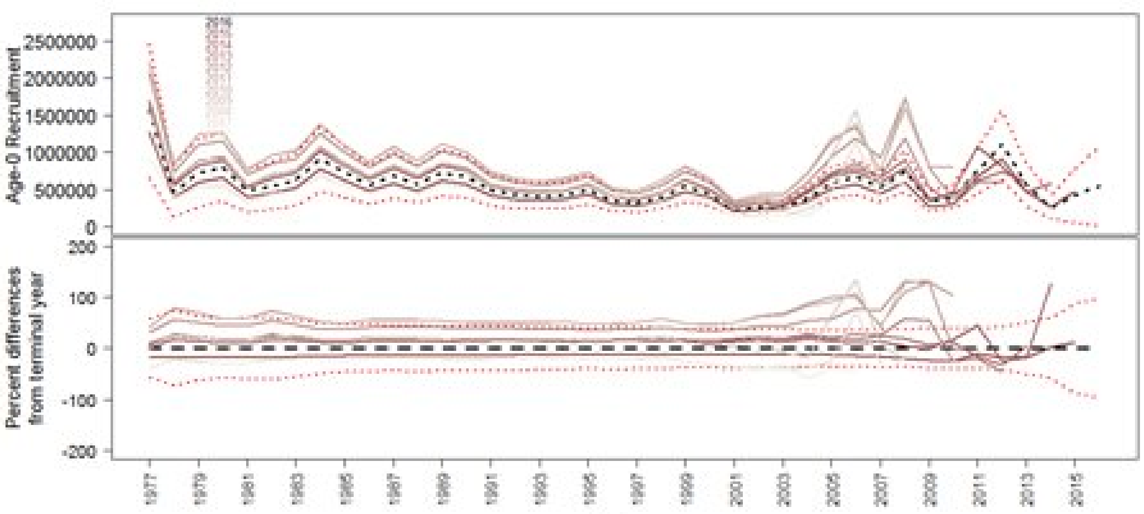
Retrospective: SSB and recruitment



Mohn's ρ = 0.094

Woods Hole ρ = 0.025

RMSE = 0.108



Mohn's ρ = 0.233

Woods Hole ρ = 0.175

RMSE = 0.327

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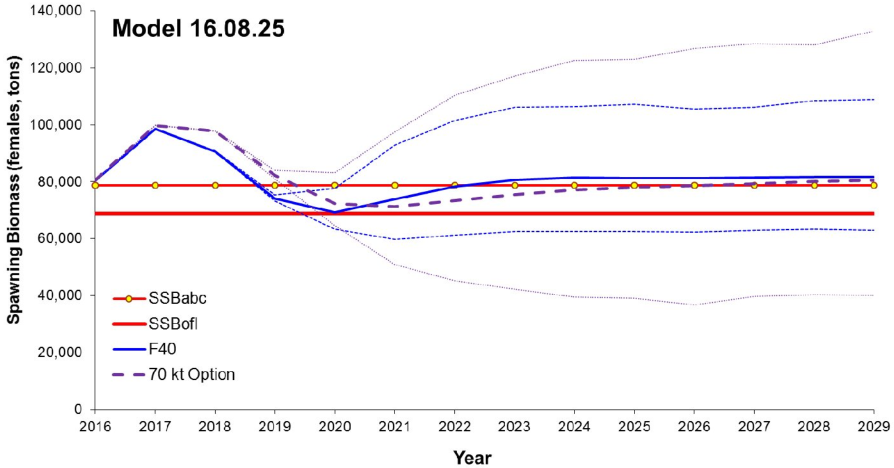
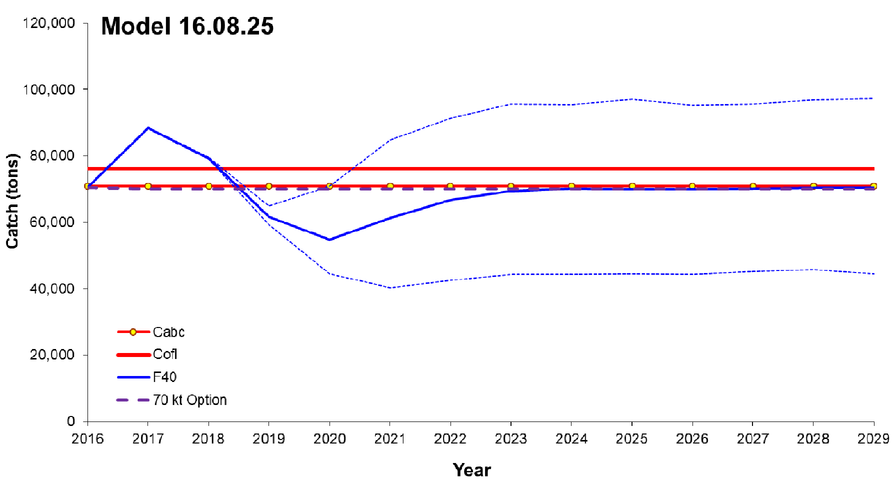
Model 16.08.25 results: Projections and recommendations

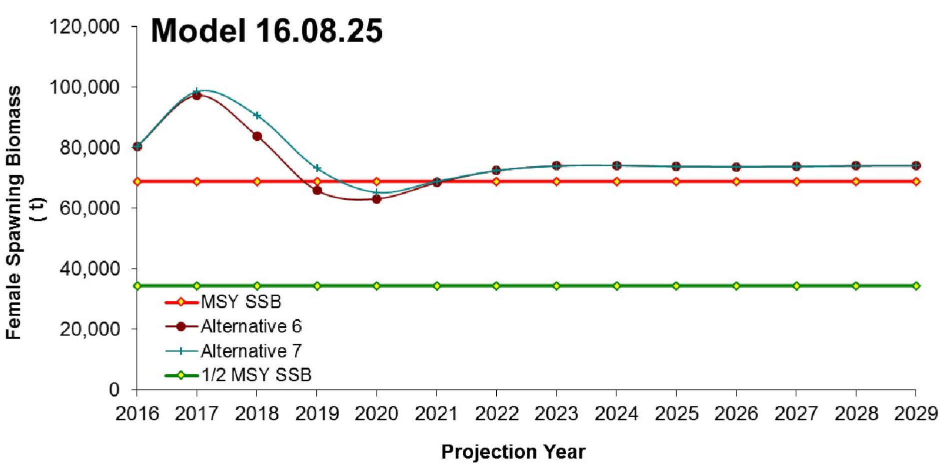




Quantity	As estimated or specified last year for: 2016	2017	As estimated or specified this year for: 2017	2018
M (natural mortality rate)	0.38	0.38	0.47	0.47
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	518,800	472,800	426,384	428,885
Female spawning biomass (t)				
Projected	165,600	141,800	98,479	90,572
$B_{100\%}$	325,200	325,200	196,776	196,776
$B_{40\%}$	130,000	130,000	78,711	78,711
$B_{35\%}$	113,800	113,800	68,872	68,872
F_{OFL}	0.495	0.495	0.652	0.652
$maxF_{ABC}$	0.407	0.407	0.530	0.530
F_{ABC}	0.407	0.407	0.530	0.530
OFL (t)	116,700	116,700	**105,378**	**94,188**
maxABC (t)	98,600	85,200	**88,342**	**79,272**
ABC (t)	98,600	85,200	**88,342**	**79,272**

Model 16.08.25 results: Projections and status

Not overfished, overfishing, or approaching an overfished condition



	As estimated or specified last year for:		As estimated or specified this year for:	
Quantity	2016	2017	2017	2018
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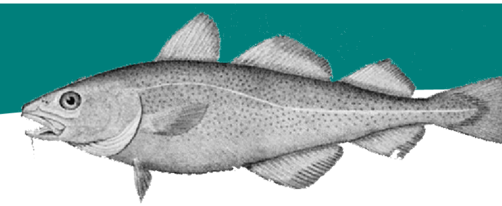
$B_{40\%}$	130,000	130,000	78,711	78,711
$B_{35\%}$	113,800	113,800	68,872	68,872
	As determined last year for:		As determined this year for:	
Status	2014	2015	2015	2016
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Near future work

1. Re-do Stark (2007) to refine maturity and natural mortality estimates with new age estimates.
2. Improve weight at length estimation.
3. Evaluate trawl survey catchability and selectivity and relationship with environmental covariates within model.
4. Evaluate cod density differences in trawlable and untrawlable habitat, particularly for 50 – 80 cm fish, using fishery dependent data.
5. Develop alternative survey strategies for untrawlable habitat.
6. Clarify stock boundaries through tagging and genetics.



Other future work

1. Investigate ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment.
2. Assess behavior of the Pacific cod fishery, including spatial dynamics.
3. Investigate ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience.
4. Develop multispecies models which take into account the ecology of species that interact with Pacific cod, for estimation of biomass, carrying capacity, and resilience.