BSAI Flathead Sole/Bering Flounder

Carey McGilliard

Overview:

- Flathead sole and Bering flounder are morphologically similar congeners, but we do not know if they are 2 different species or not
  - Bering flounder like cold water; flathead sole seem to avoid the cold pool
  - Bering flounder don’t grow as large as flathead sole

- 2017 and 2018 Northern Bering Sea survey showed 10x as many Bering flounder (~30,0000) as for the EBS shelf survey, but flathead sole population still mostly on the EBS shelf

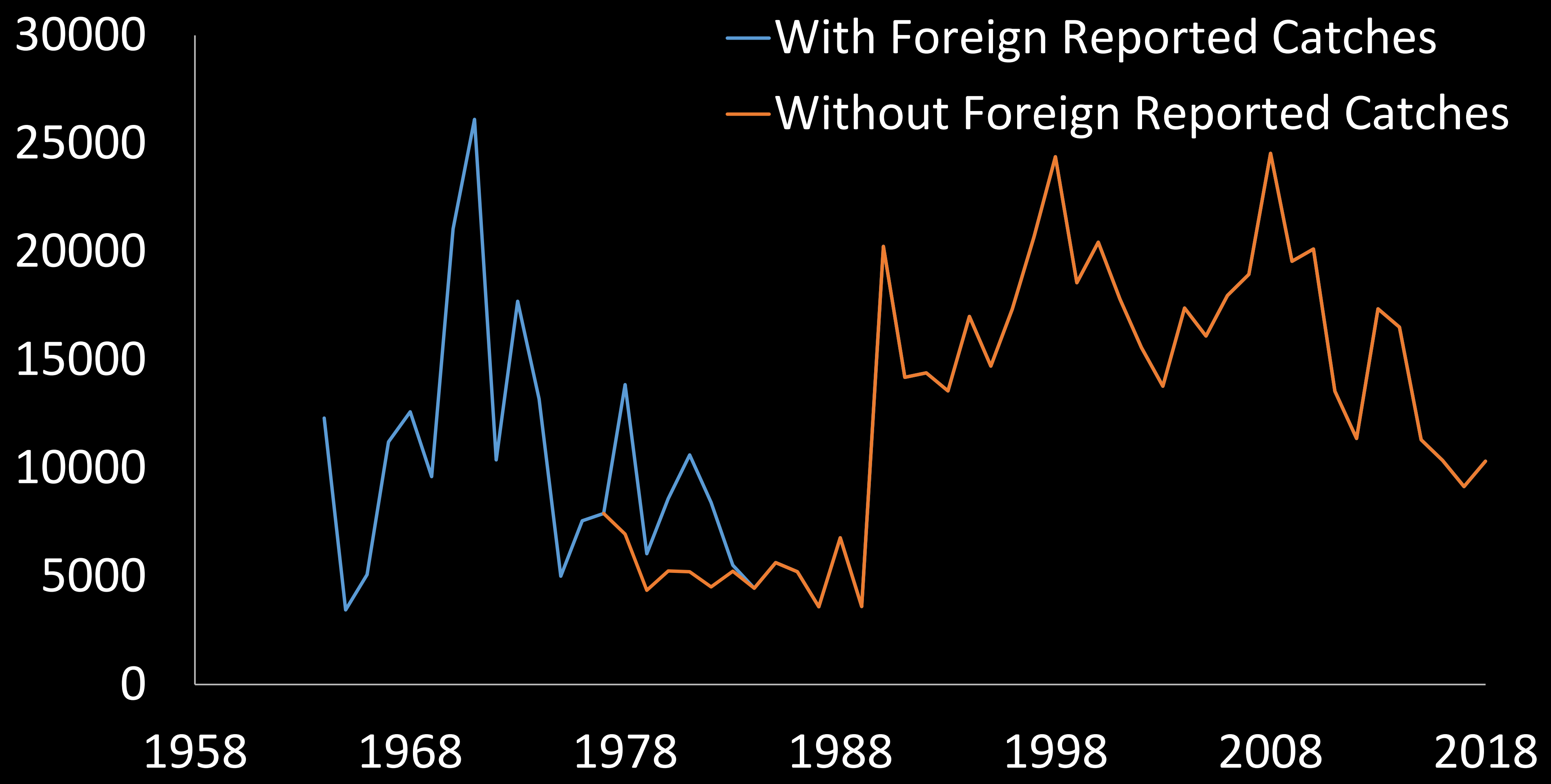
Overview, continued:

- TAC always much lower than ABC, realized catch lower than TAC

- Flathead sole are harder to find than yellowfin or Northern rock sole, prior to 2008 there were some fishery closures due to halibut bycatch

- 2016 assessment issues:
  - Retrospective bias related to survey selectivity parameters + unrealistic survey selectivity curve
  - A distinct pattern in residuals for fits to survey and fishery length composition data, recurring over time
  - An unrealistic estimate of historical mean recruitment (54 million age 3 recruits prior to 1977 and 835 million recruits after 1977)
  - Temperature-catchability relationship does not seem to hold anymore

Catch of flathead sole/Bering flounder:



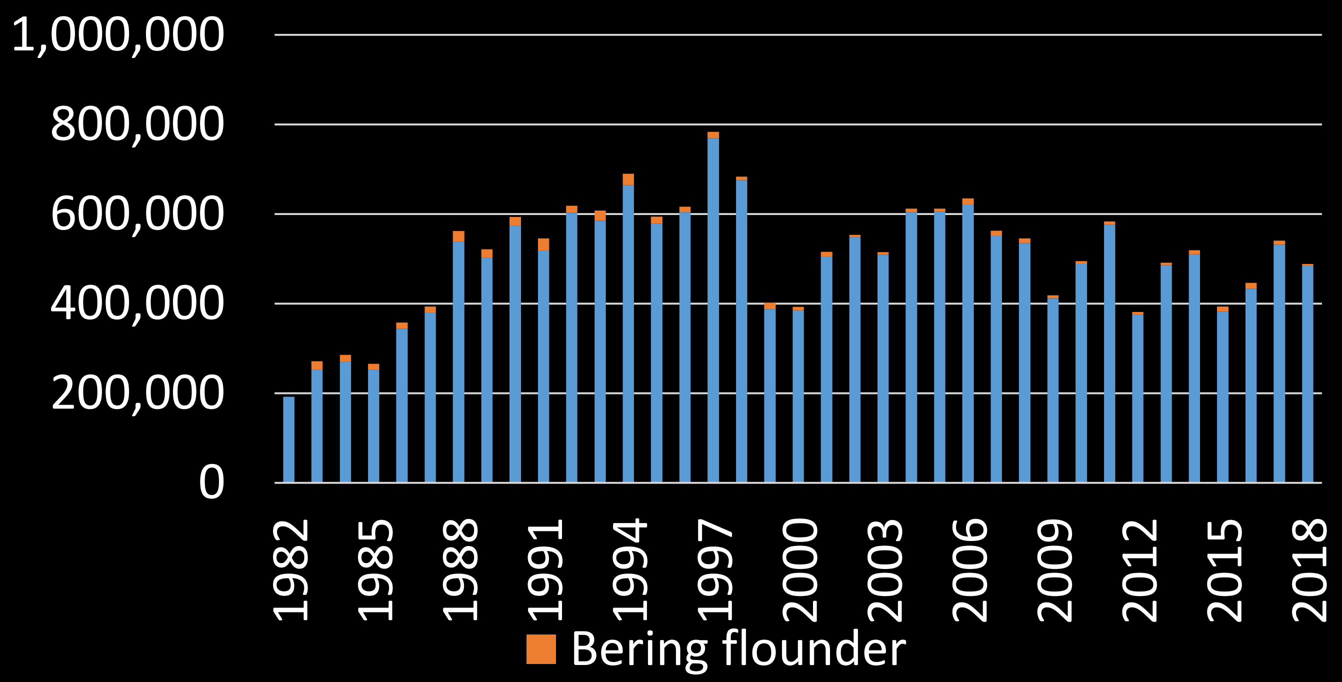
The fishery:

	NMFS Area														
Year	**508**	**509**	**512**	**513**	**514**	**516**	**517**	**518**	**519**	**521**	**523**	**524**	**541**	**542**	**543**
1992	0.00	0.14	0.00	0.19	0.05	0.01	0.16	0.00	0.02	0.40	0.02	0.01	0.00	0.00	0.00
1993	0.00	0.19	0.00	0.39	0.02	0.01	0.12	0.00	0.00	0.24	0.01	0.01	0.00	0.00	0.00
1994	0.00	0.14	0.00	0.37	0.00	0.03	0.25	0.00	0.01	0.18	0.00	0.01	0.00	0.00	0.00
1995	0.00	0.19	0.00	0.40	0.01	0.01	0.27	0.00	0.01	0.12	0.00	0.00	0.00	0.00	0.00
1996	0.00	0.32	0.00	0.34	0.00	0.01	0.25	0.00	0.01	0.06	0.00	0.01	0.00	0.00	0.00
1997	0.00	0.18	0.00	0.36	0.01	0.00	0.34	0.00	0.01	0.09	0.00	0.01	0.00	0.00	0.00
1998	0.00	0.22	0.00	0.25	0.00	0.00	0.33	0.00	0.01	0.18	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.12	0.00	0.40	0.00	0.02	0.31	0.00	0.01	0.14	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.18	0.00	0.40	0.00	0.00	0.23	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.13	0.00	0.32	0.00	0.02	0.14	0.00	0.01	0.30	0.01	0.05	0.00	0.00	0.00
2002	0.00	0.11	0.00	0.28	0.00	0.01	0.16	0.00	0.01	0.42	0.00	0.01	0.00	0.00	0.00
2003	0.00	0.13	0.00	0.34	0.01	0.02	0.08	0.00	0.00	0.36	0.00	0.05	0.00	0.00	0.00
2004	0.00	0.13	0.00	0.23	0.00	0.02	0.11	0.00	0.01	0.48	0.00	0.01	0.00	0.00	0.00
2005	0.00	0.14	0.00	0.25	0.00	0.01	0.13	0.00	0.00	0.27	0.00	0.18	0.00	0.00	0.00
2006	0.00	0.21	0.00	0.17	0.00	0.01	0.13	0.00	0.00	0.41	0.00	0.06	0.00	0.00	0.00
2007	0.00	0.15	0.00	0.19	0.00	0.01	0.23	0.00	0.01	0.35	0.00	0.05	0.00	0.00	0.00
2008	0.00	0.26	0.00	0.24	0.00	0.01	0.15	0.00	0.00	0.27	0.00	0.06	0.00	0.00	0.00
2009	0.00	0.25	0.00	0.23	0.00	0.01	0.15	0.00	0.00	0.32	0.00	0.03	0.00	0.00	0.00
2010	0.00	0.23	0.00	0.26	0.00	0.03	0.11	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.25	0.00	0.28	0.00	0.01	0.17	0.00	0.00	0.27	0.00	0.01	0.00	0.00	0.00
2012	0.00	0.17	0.00	0.18	0.02	0.01	0.18	0.00	0.01	0.41	0.00	0.02	0.00	0.00	0.00
2013	0.00	0.19	0.00	0.16	0.00	0.01	0.28	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.20	0.00	0.18	0.01	0.01	0.24	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.15	0.00	0.35	0.05	0.01	0.07	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.17	0.00	0.54	0.05	0.02	0.09	0.00	0.02	0.09	0.00	0.01	0.00	0.00	0.00
2017	0.00	0.20	0.00	0.51	0.02	0.01	0.11	0.00	0.01	0.12	0.00	0.01	0.00	0.00	0.00
2018	0.00	0.12	0.00	0.45	0.02	0.01	0.14	0.00	0.01	0.14	0.00	0.11	0.00	0.00	0.00

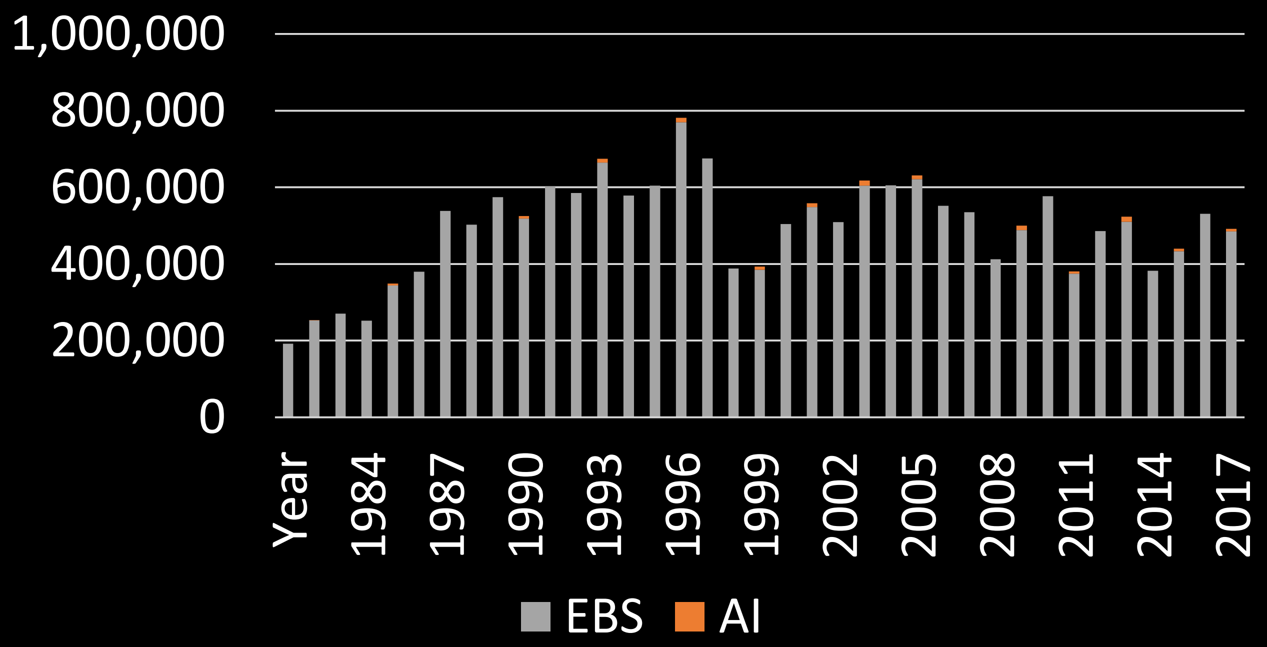
Year	**Non-Pelagic Trawl**	**Pelagic Trawl**	**Pair Trawl**	**Shrimp Trawl**	**Pot or Trap**	**Longline**
1992	0.52	0.45	0.00	0.00	0.00	0.03
1993	0.85	0.14	0.00	0.00	0.00	0.02
1994	0.89	0.09	0.00	0.00	0.00	0.02
1995	0.85	0.13	0.00	0.00	0.00	0.02
1996	0.79	0.19	0.00	0.00	0.00	0.02
1997	0.81	0.16	0.00	0.00	0.00	0.03
1998	0.86	0.12	0.00	0.00	0.00	0.02
1999	0.76	0.21	0.00	0.00	0.00	0.02
2000	0.77	0.21	0.00	0.00	0.00	0.02
2001	0.74	0.23	0.00	0.00	0.00	0.02
2002	0.73	0.24	0.00	0.00	0.00	0.03
2003	0.75	0.21	0.00	0.00	0.00	0.04
2004	0.76	0.20	0.00	0.00	0.00	0.04
2005	0.74	0.22	0.00	0.00	0.00	0.05
2006	0.73	0.24	0.00	0.00	0.00	0.03
2007	0.67	0.31	0.00	0.00	0.00	0.02
2008	0.83	0.16	0.00	0.00	0.00	0.01
2009	0.80	0.19	0.00	0.00	0.00	0.01
2010	0.79	0.20	0.01	0.00	0.00	0.01
2011	0.63	0.35	0.00	0.00	0.00	0.02
2012	0.64	0.34	0.00	0.00	0.00	0.02
2013	0.82	0.17	0.00	0.00	0.00	0.01
2014	0.83	0.14	0.00	0.00	0.00	0.02
2015	0.78	0.20	0.00	0.00	0.00	0.03
2016	0.83	0.15	0.00	0.00	0.00	0.03
2017	0.86	0.10	0.00	0.00	0.00	0.04
2018	0.87	0.10	0.00	0.00	0.00	0.02

Survey Biomass

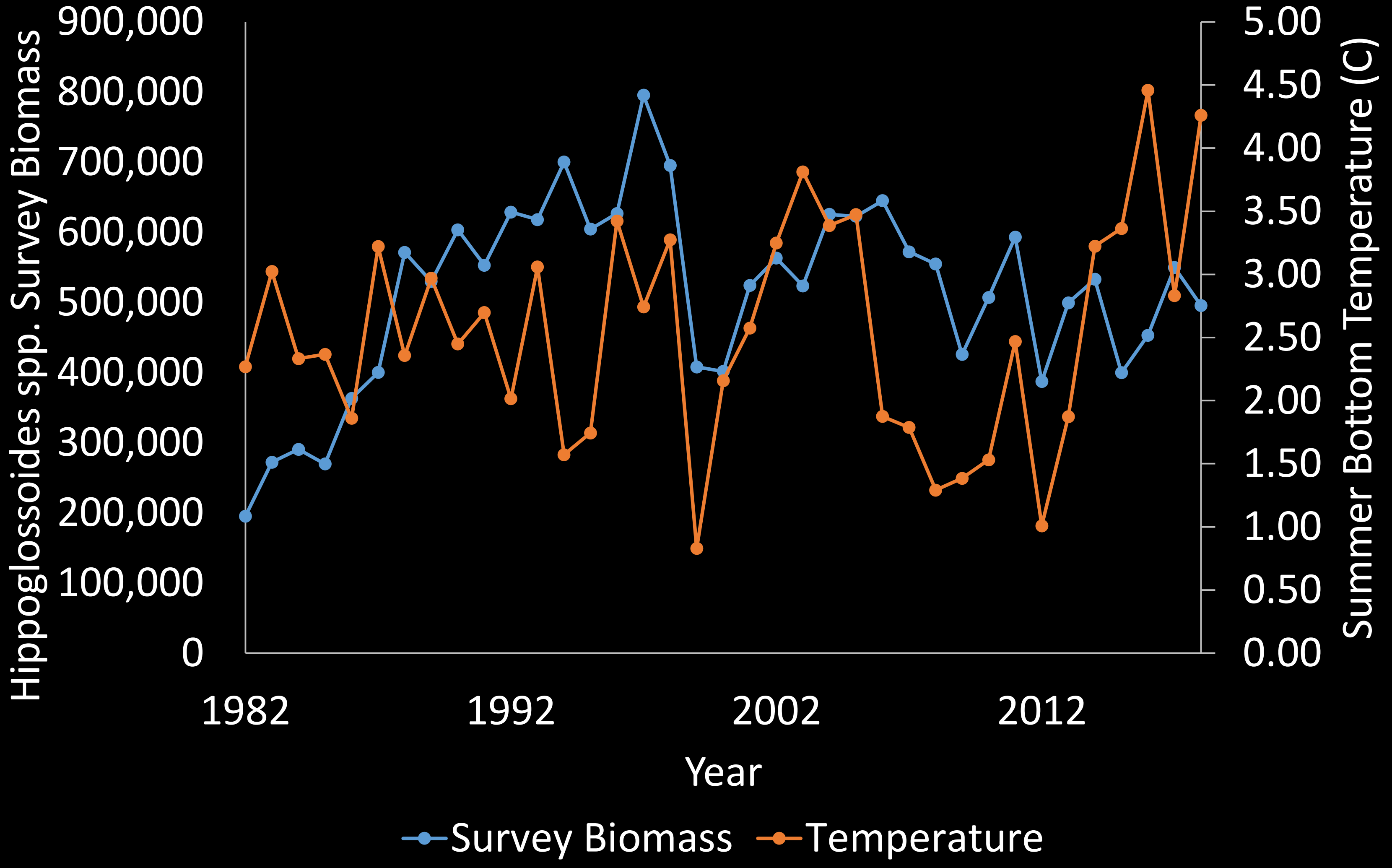
Flathead sole:Bering flounder



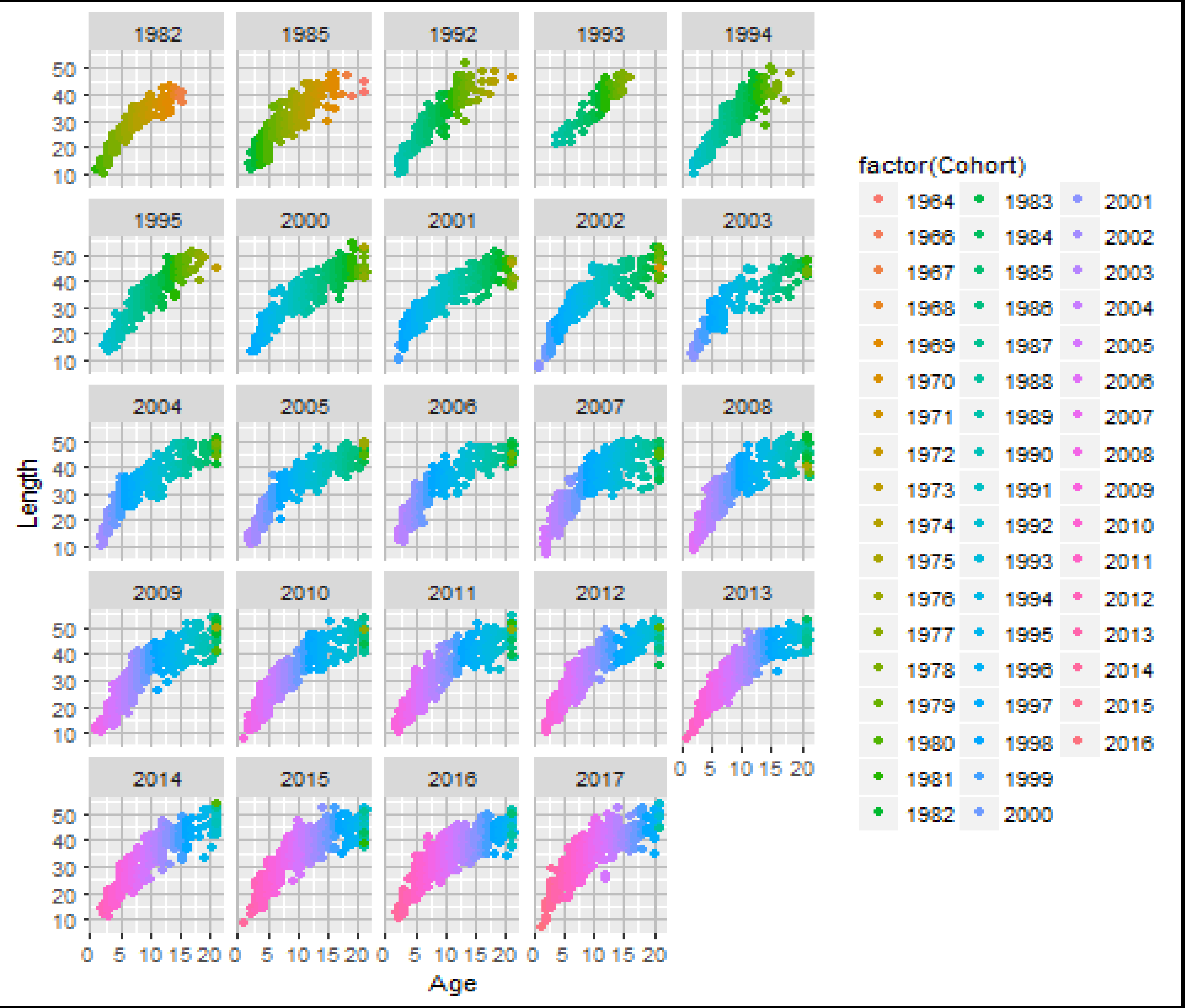
EBS shelf:AI Flathead sole



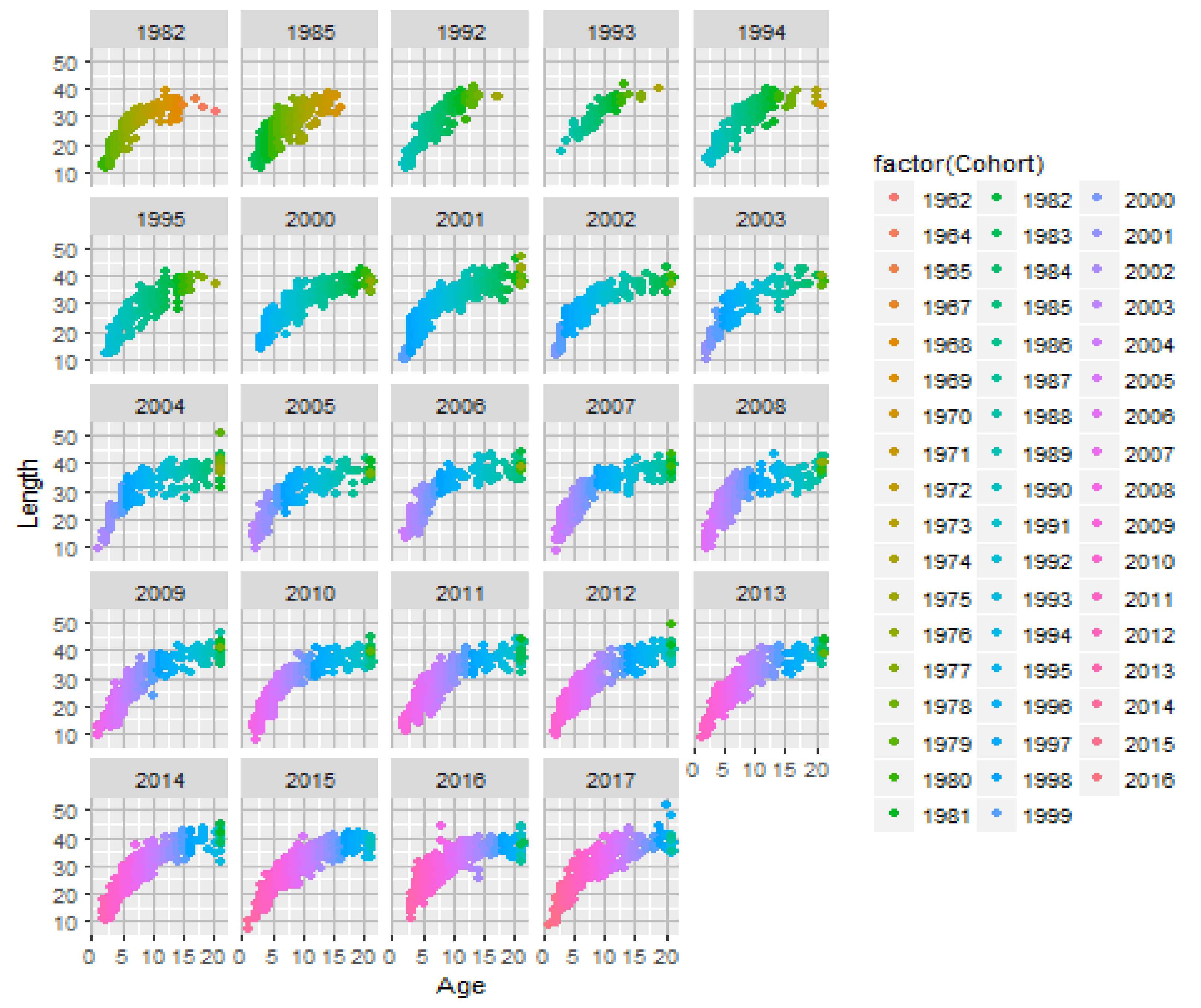
Is there a relationship between survey biomass and bottom temperature?



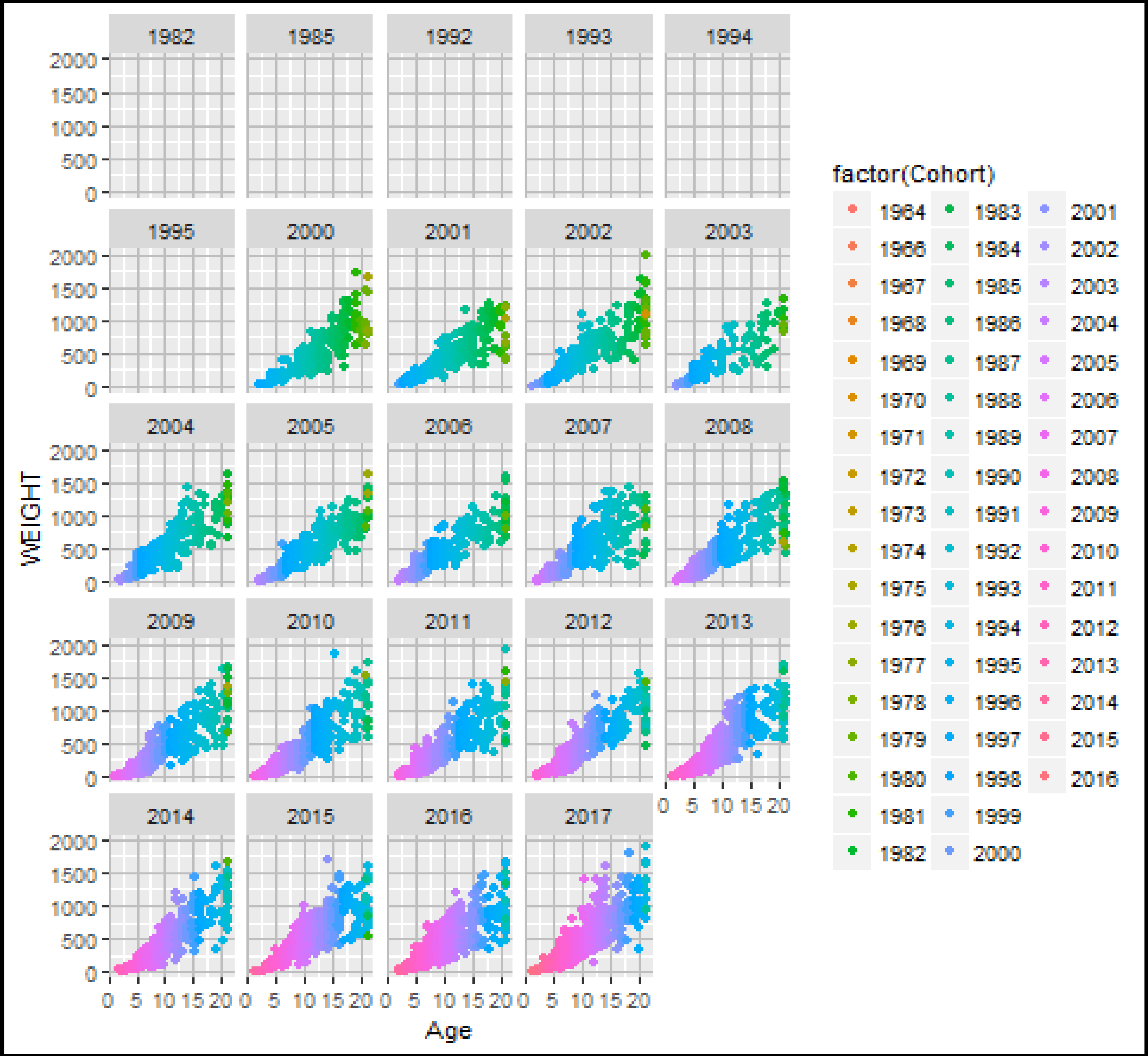
Data exploration: Female length-at-age by cohort and year of flathead sole from the EBS shelf survey



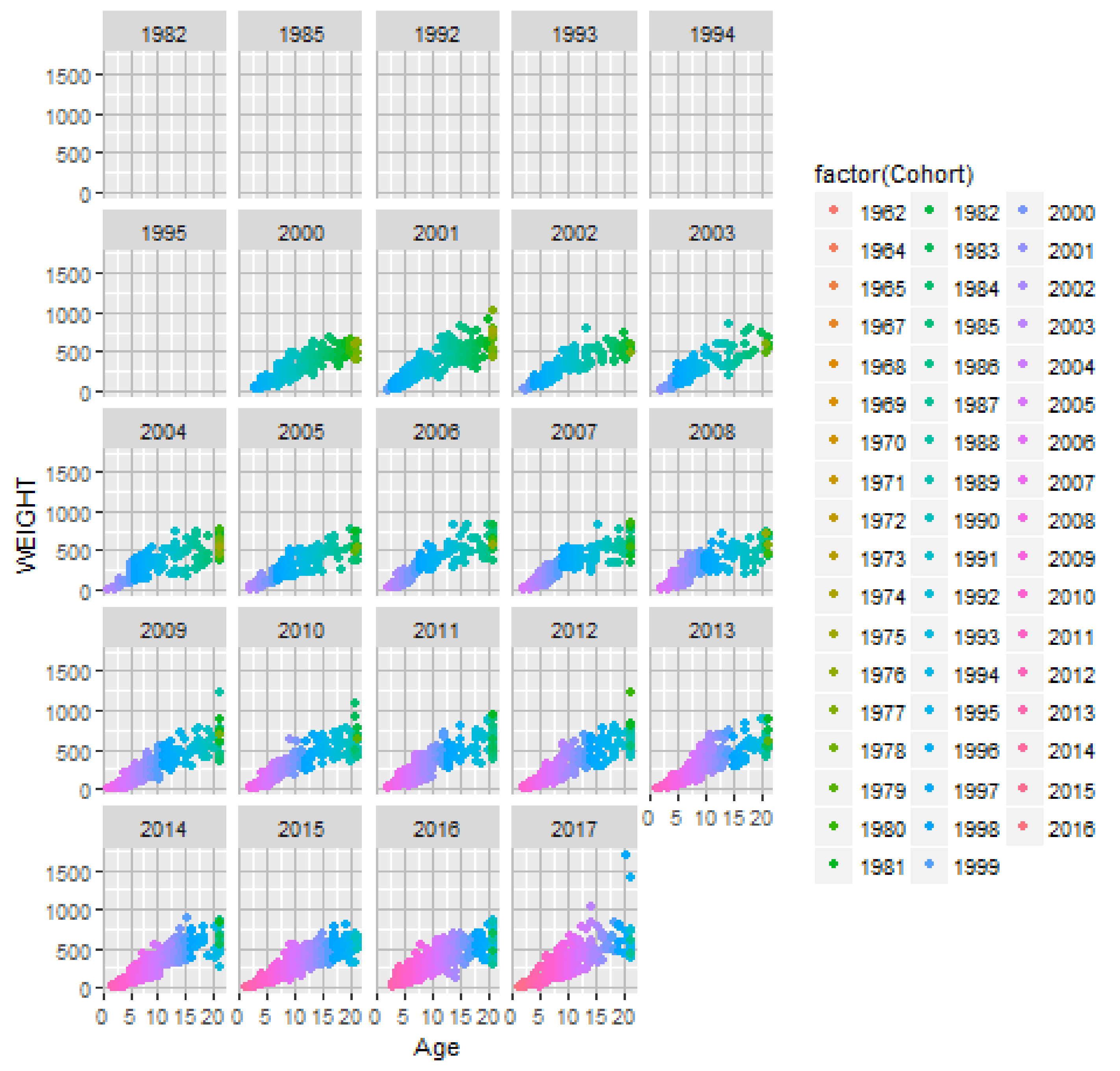
Data exploration: Male length-at-age by cohort and year of flathead sole from the EBS shelf survey



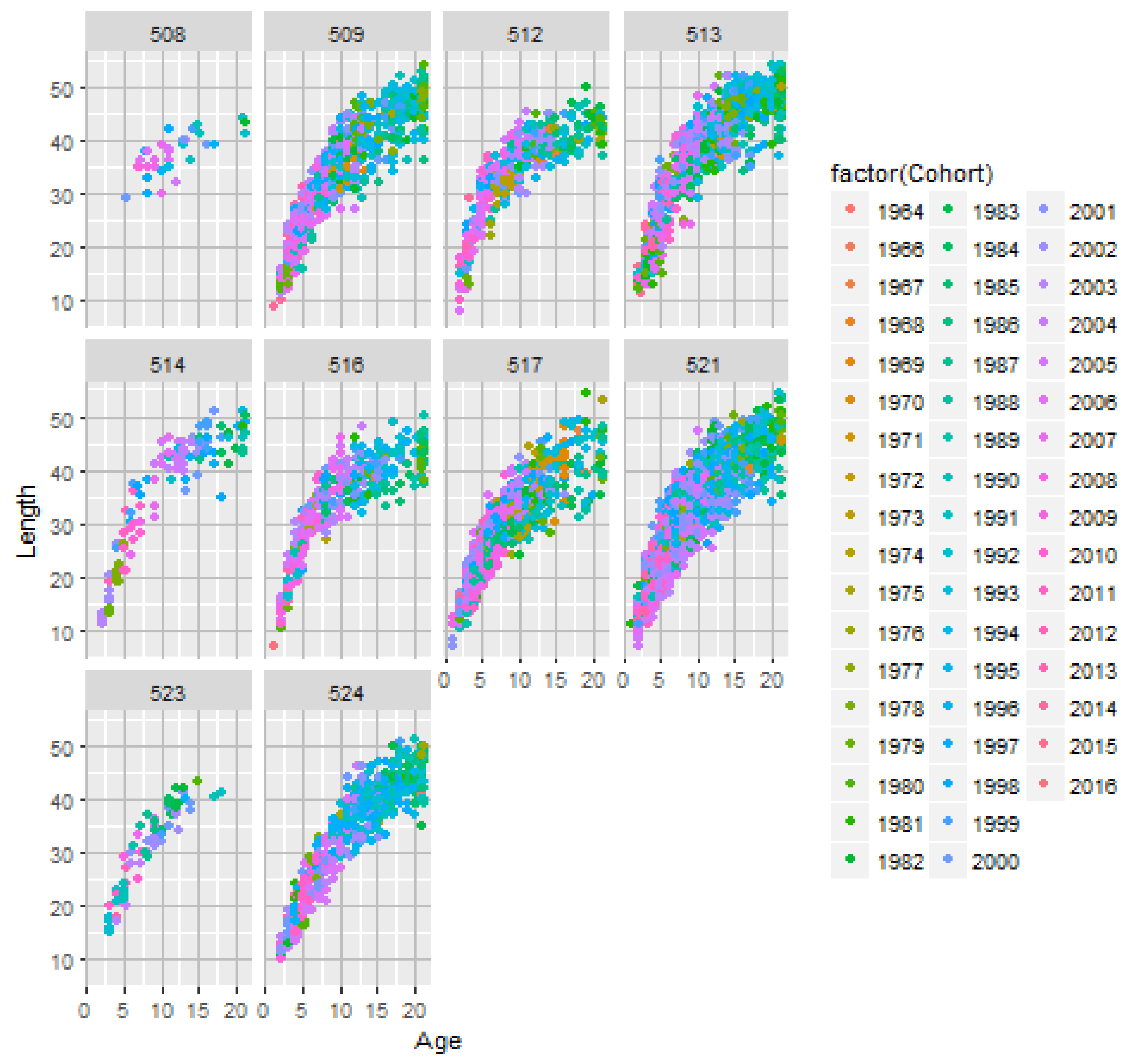
Data exploration: Female weight-at-age by cohort and year of flathead sole from the EBS shelf survey



Data exploration: Male weight-at-age by cohort and year of flathead sole from the EBS shelf survey



Data exploration: Female length-at-age by cohort and NMFS area of flathead sole from the EBS shelf survey



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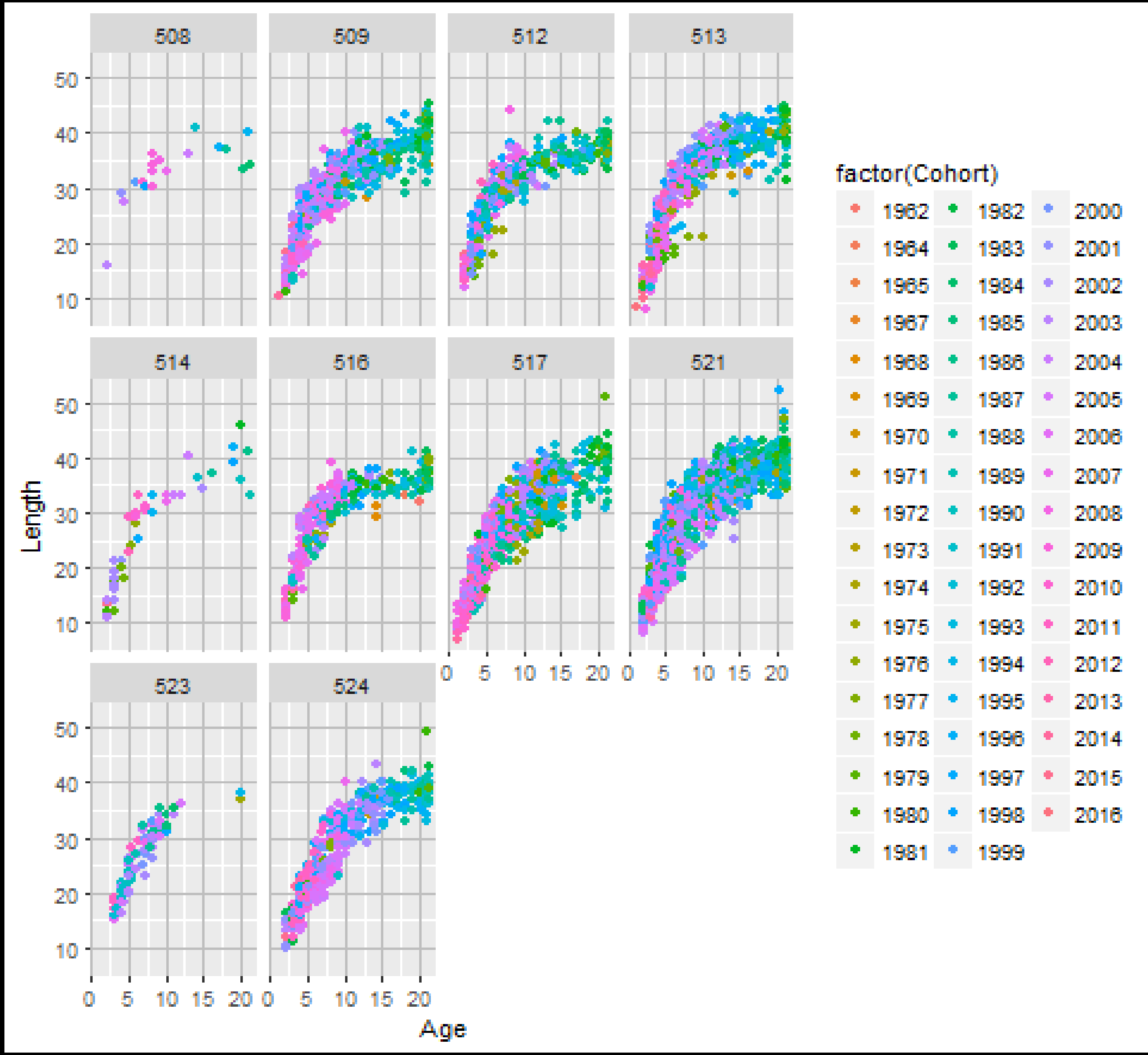

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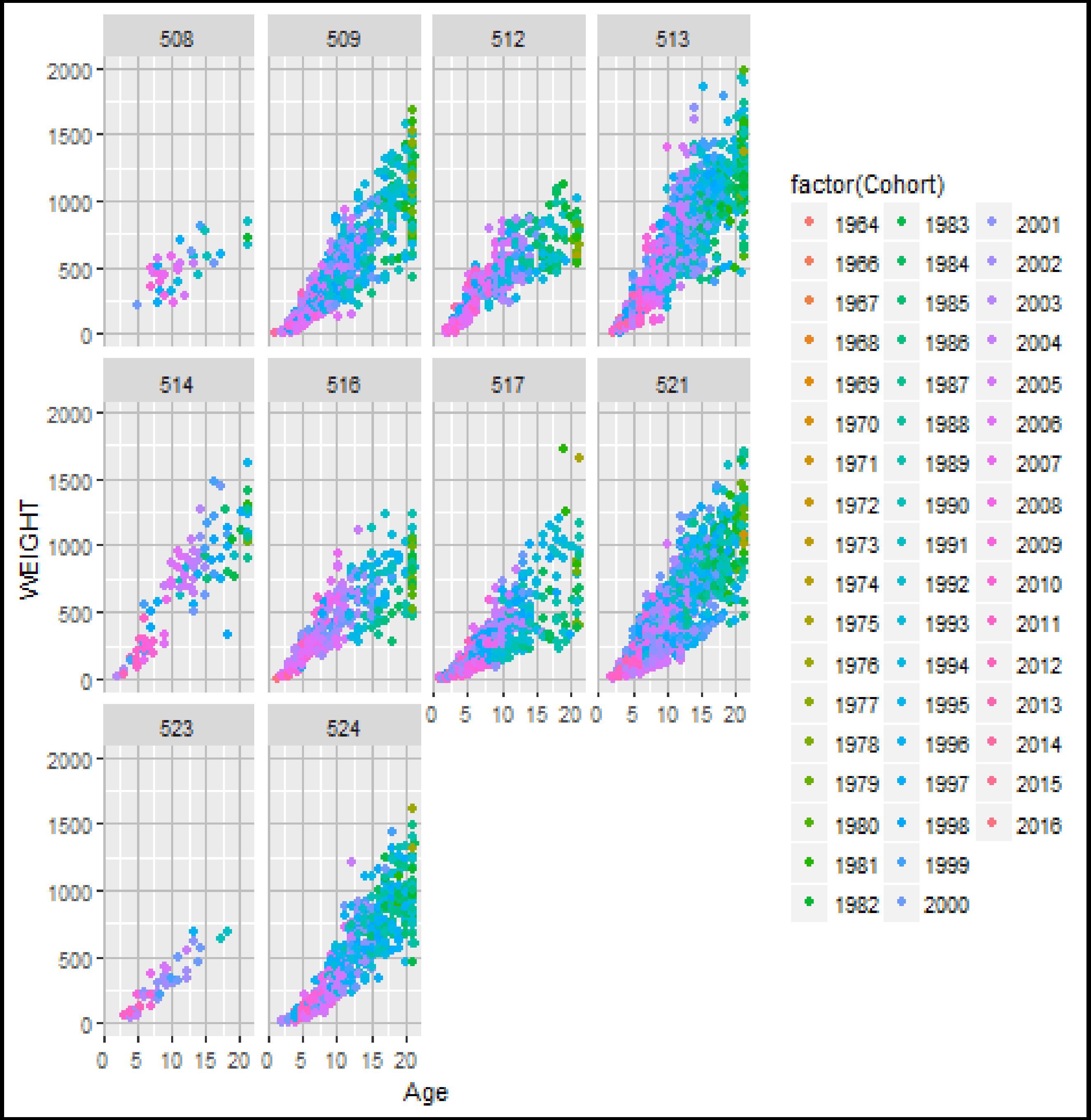

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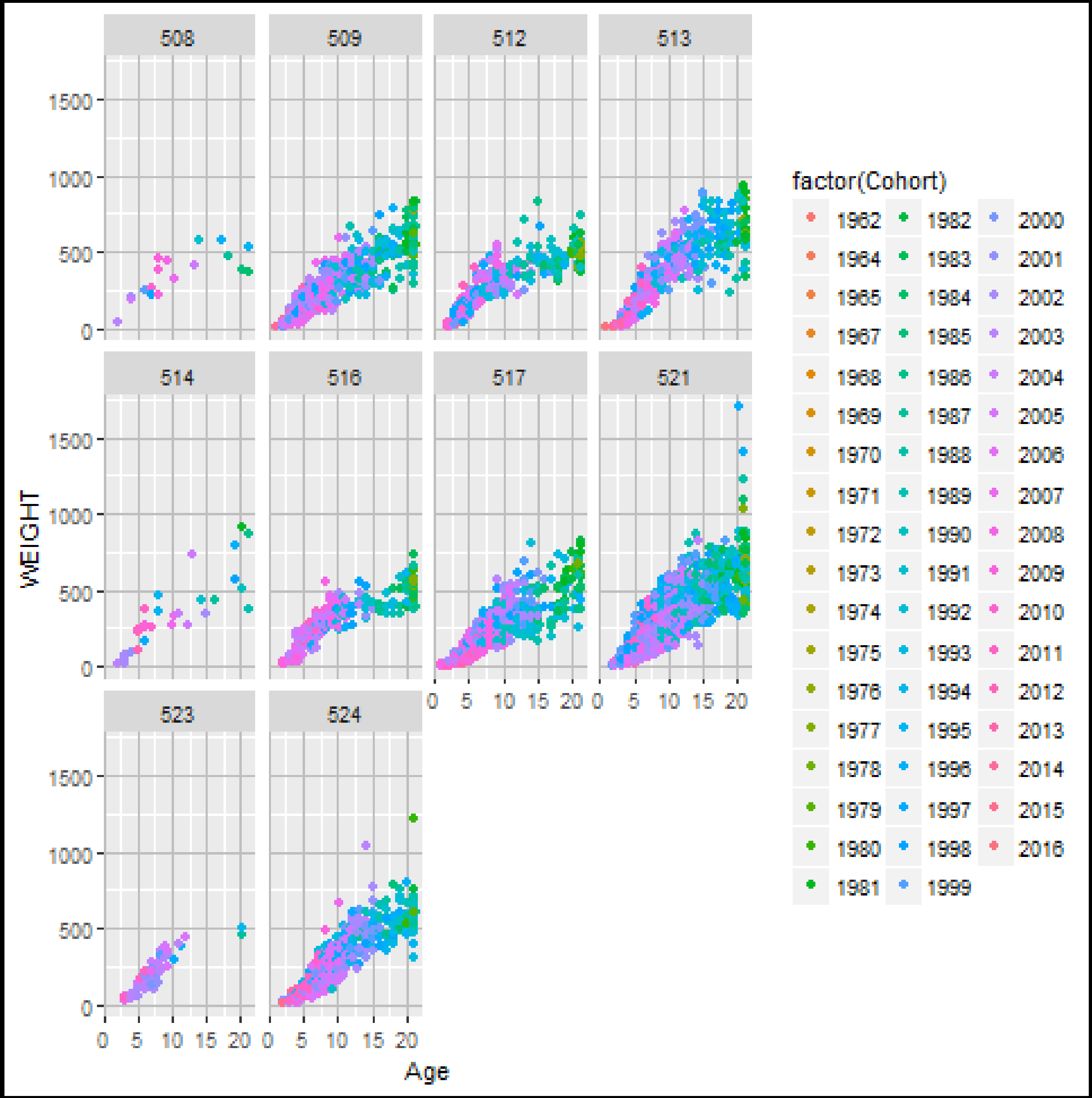


Survey data exploration: More in Appendix D of the document

- Weight-length by cohort and year
- Plots shown for Bering flounder

In September:

- Switched to Stock Synthesis framework for assessment
- Presented an exercise completed to compare the 2016 model to the best-matching model in Stock Synthesis
- Presented updated/improved models in Stock Synthesis beyond the best matching model
- Two models were recommended by the SSC to move forward for November: Model 18.0 and 18.0b (like Model 18.0, but with fishery selectivity estimated in 3 separate management eras)
- Plan Team thought just Model 18.0b was sufficient for November (along with 2016 model with updated data)

In September:

- Promised to do some data exploration
- Plan Team agreed to a run with growth estimated within the assessment model based on conditional age-at-length data

Notable changes in inputs presented in September:

- 1964-1987 foreign reported catches added
- Historical catch prior to 1964 was set equal to the average catch from 1964-1977 (11,659 t).

Model changes presented in September:

- Used Stock Synthesis framework (2016 model with 2018 data presented in Appendix)
- Modeled male and female survey selectivity as separate curves using an age-based double-normal asymptotic curve to provide for additional flexibility in the curve’s shape.
- Age- and length-composition data were weighted using methods described in Francis (2011) to approximate effective sample size for each year and data type for all models 18.0-18.2 variants.
- Recruitment deviations were estimated through 2014 for age 0 recruits.
- A sum-to-zero constraint was used in the likelihood component for recruitment deviations.
- Historical mean recruitment was set equal to non-historical mean recruitment.
- The temperature-catchability relationship that was assumed in the 2012, 2014, and 2016 models was removed from the model.
- A model was run with separate fishery selectivity curves for three management eras (recommended by Plan Team to move forward for November)

Models:

Models 18.*x*:

- Time invariant fishery selectivity curves

Models 18.*x*b:

- Separate fishery selectivity curves for the time period 1964-1988, 1989-2007, and 2008+.

Models 18.*x*c:

- Separate fishery selectivity curves for the time period 1964-1988, 1989+

Models 18.0x:

- Shown in September (external estimation of growth, equal input sample sizes for comp data)

Models 18.1*x*

- Estimated growth within the assessment model using a conditional age-at-length approach Male and female fishery selectivity were estimated as separate curves

Models 18.2*x:*

- Used the number of hauls from which length data originated as input sample sizes for survey and fishery length and age compositions (Pennington and Volstad)

SSC Comments in general:

- The risk matrix: did not seem necessary for flathead sole – well above B40% and no indicators of higher natural mortality or low fish condition, etc.
- Ensemble modeling: all of the candidate models for 2018 were highly correlated and ensemble modeling would not have yielded different results

SSC/Plan Team Comments for flathead sole/Bering flounder:

- BSAI Plan Team: The Team recommends examining the use of time blocks in selectivity due to changes in fishing practices:
  - Some 2018 models incorporated time blocks on fishery selectivity for the 1964-1987 and 1988-2007 management eras.

Data used in the assessment:

Source	**Data**	**Species Included**	**Years**
NMFS Aleutian Islands Groundfish Trawl Survey	Survey biomass (linear regression used to combine BS shelf survey estimates with AI survey estimates for a single survey biomass index)	Flathead only; no Bering flounder were caught in the Aleutian Islands	1980, 1983, 1986, 1991-2000 (triennial), 2002-2006 (biennial), 2010-2018 (biennial)

Data used in the assessment:

Source	**Data**	**Species Included**	**Years**
NMFS Bering Sea Shelf Groundfish Survey (standard survey area only[1])	Survey biomass (linear regression used to combine BS shelf survey estimates with AI survey estimates for a single survey biomass index)	Flathead sole and Bering flounder combined	1982-2018
	Age Composition	Flathead sole only	1982, 1985, 1992-1995, 2000-2017
	Length Composition	Flathead sole only	1983, 1984, 1986-1991, 1996-1999, 2018

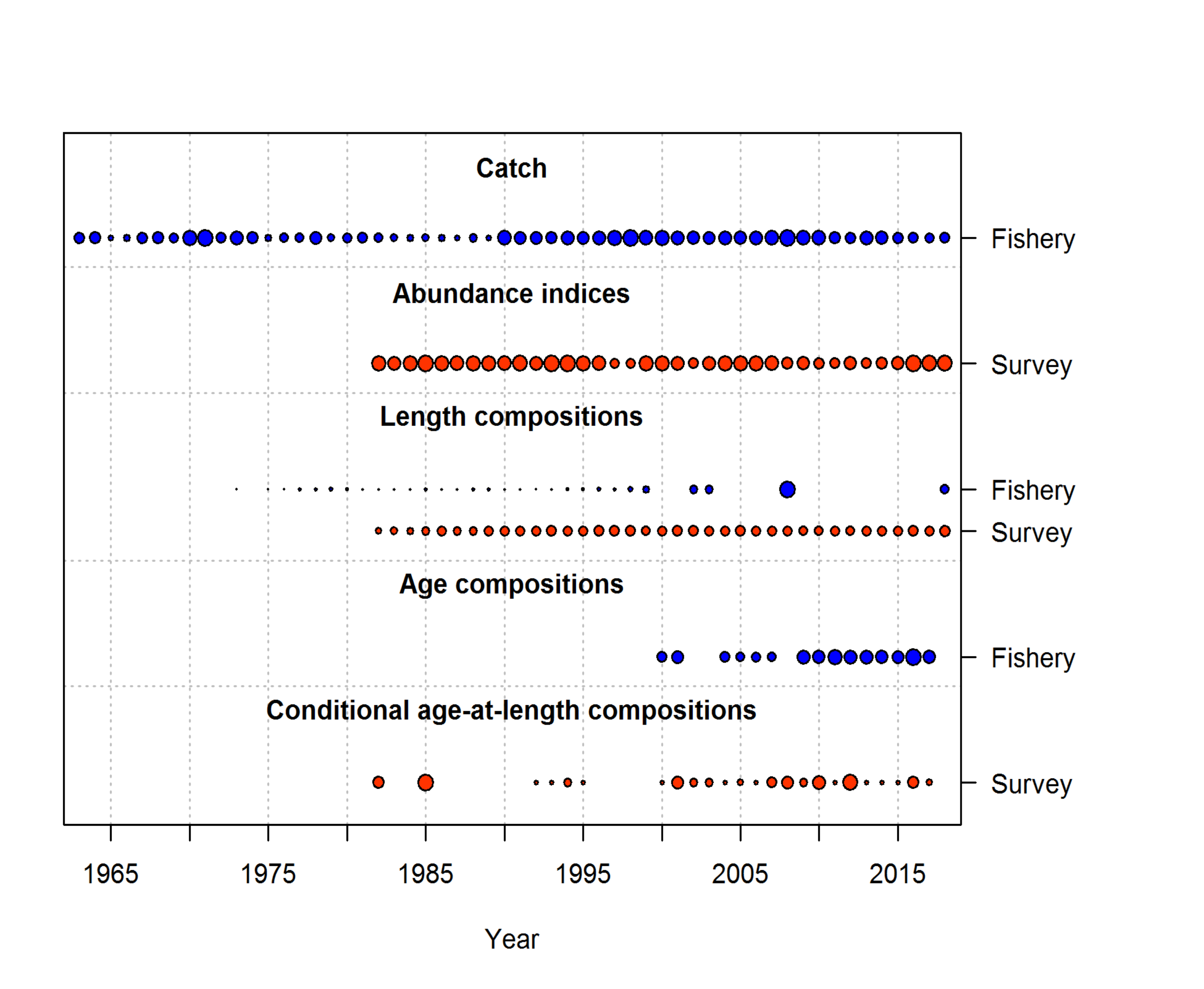
Data used in the assessment:

Source	Data	Species Included	Years
U.S. trawl fisheries	Catch (Bering Sea and Aleutian Islands; pelagic and non-pelagic trawl[2])	Flathead sole and Bering flounder combined	1977-2018
	Age Composition (Bering Sea only; non-pelagic trawl only)	Flathead sole only	1994, 1995, 1998, 2000, 2001, 2004-2007, 2009-2017
	Length Composition (Bering Sea only; non-pelagic trawl only)	Flathead sole only	1977-1993, 1994, 1996-1997, 1999, 2002-2003, 2008, 2018

Data used in the assessment:

Source	Data	Species Included	Years
Foreign trawl fisheries in the BSAI	Catch (Bering Sea and Aleutian Islands; trawl)	Flathead sole and Bering Flounder combined	1964-1987

Data used in the assessment:



Models: Models 18.0 and 18.0b requested by SSC

Models 18.*x*:

- Time invariant fishery selectivity curves

Models 18.*x*b:

- Separate fishery selectivity curves for the time period 1964-1988, 1989-2007, and 2008+.

Models 18.*x*c:

- Separate fishery selectivity curves for the time period 1964-1988, 1989+

Models 18.0x:

- Shown in September (external estimation of growth, equal input sample sizes for comp data)

Models 18.1*x*

- Estimated growth within the assessment model using a conditional age-at-length approach Male and female fishery selectivity were estimated as separate curves

Models 18.2*x:*

- Used the number of hauls from which length data originated as input sample sizes for survey and fishery length and age compositions

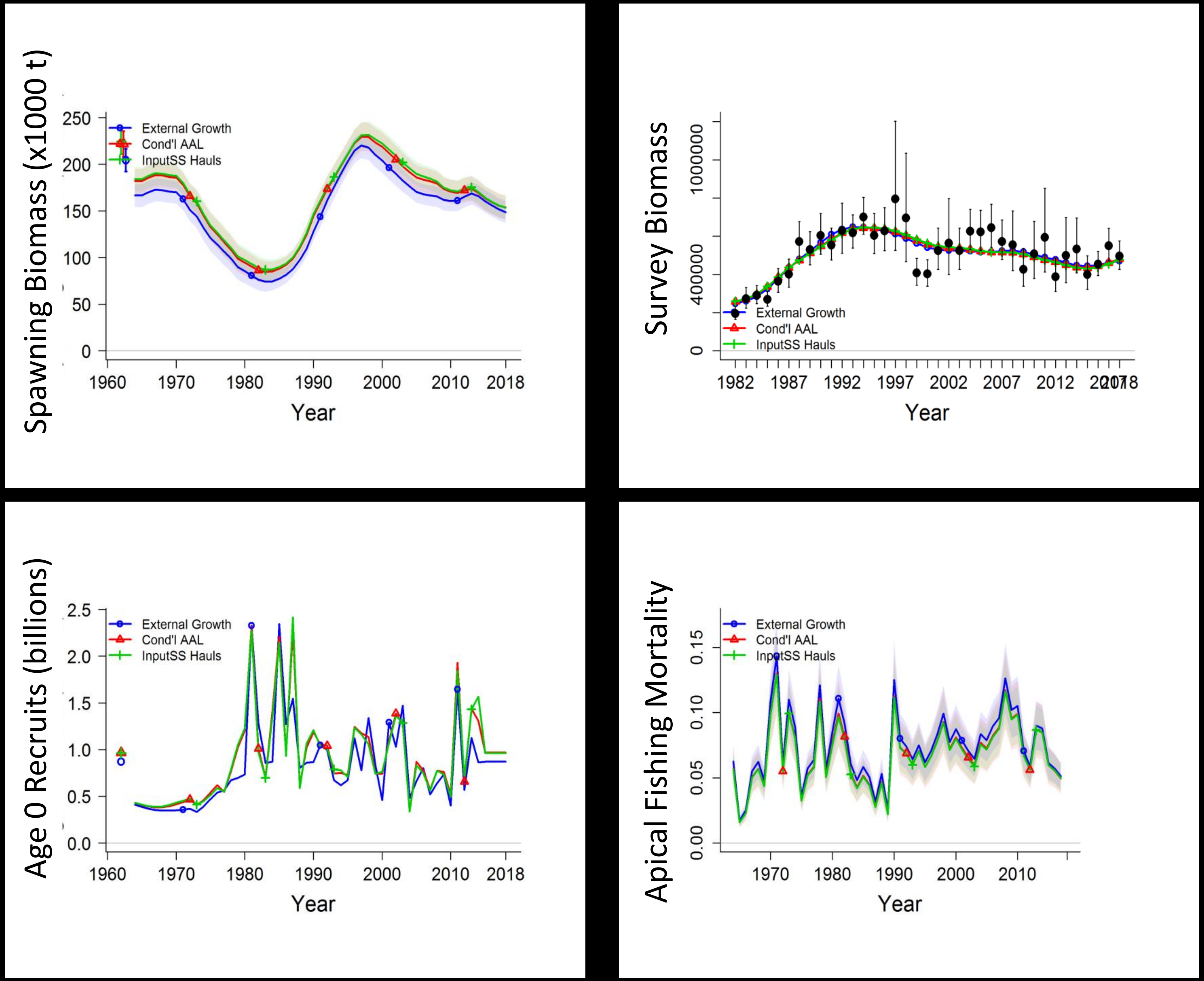
Comparing Models 18.0, 18.1, and 18.2:

- Model 18.0: time-invariant fishery selectivity, external growth estimates, input sample sizes to comp data = 200 for all years
- Model 18.1: time-invariant fishery selectivity, internal growth estimates, input sample sizes to comp data = 200 for all years
- Model 18.2: time-invariant fishery selectivity, internal growth estimates, input sample sizes to comp data = number of hauls from which data came

- Note: input sample sizes for all conditional age-at-length data were the number of ages in the sample

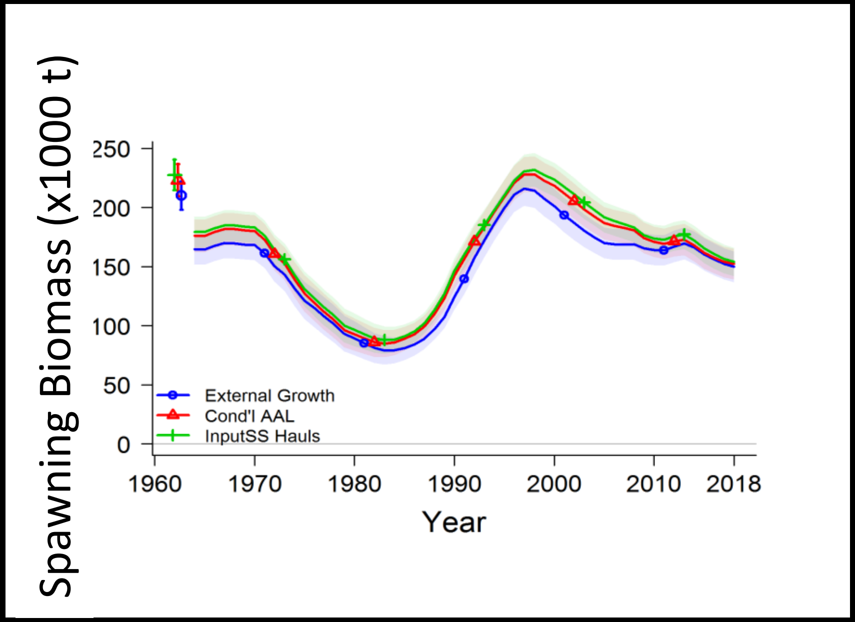
Comparing Models 18.0, 18.1, and 18.2

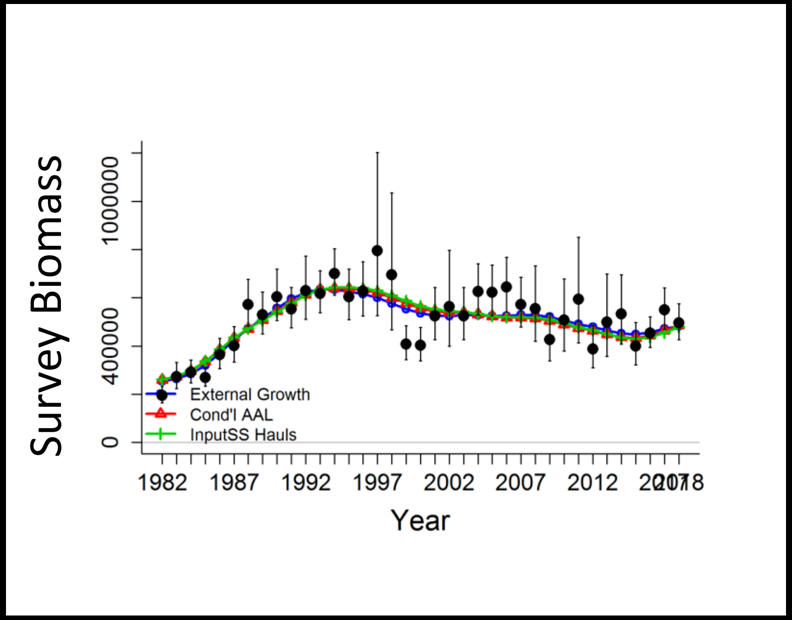
- Results are very similar
- Estimating growth internally and input sample size = # of hauls are both improvements to methodology

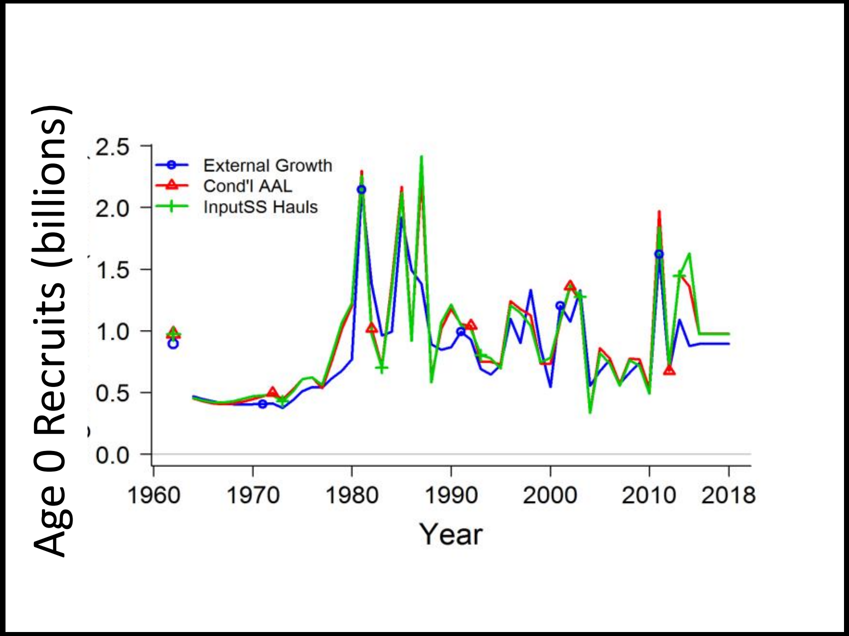


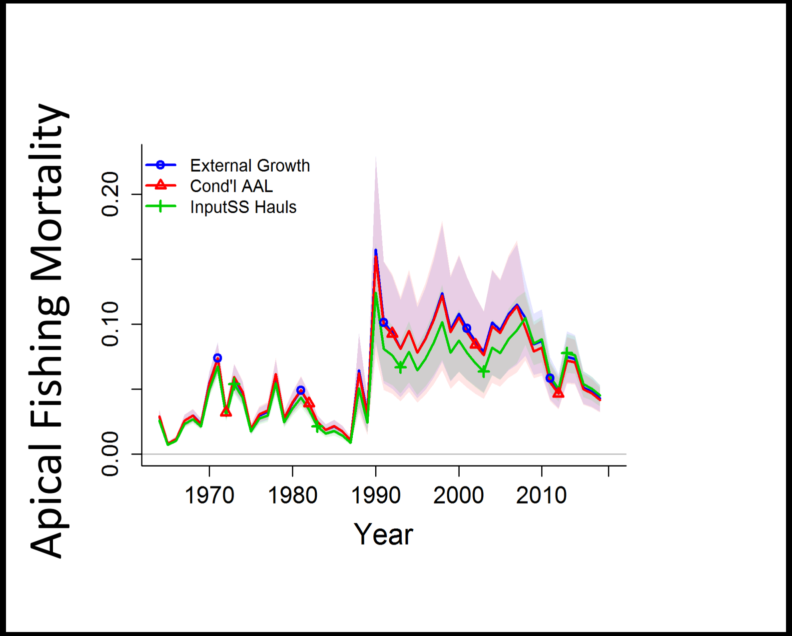
Comparing Models 18.0b, 18.1b, and 18.2b

- Results are similar
- Using input SS = hauls lowers variability in estimates of Fs during middle era (1988-2007)
- Moved forward with 18.2 and 18.2b only

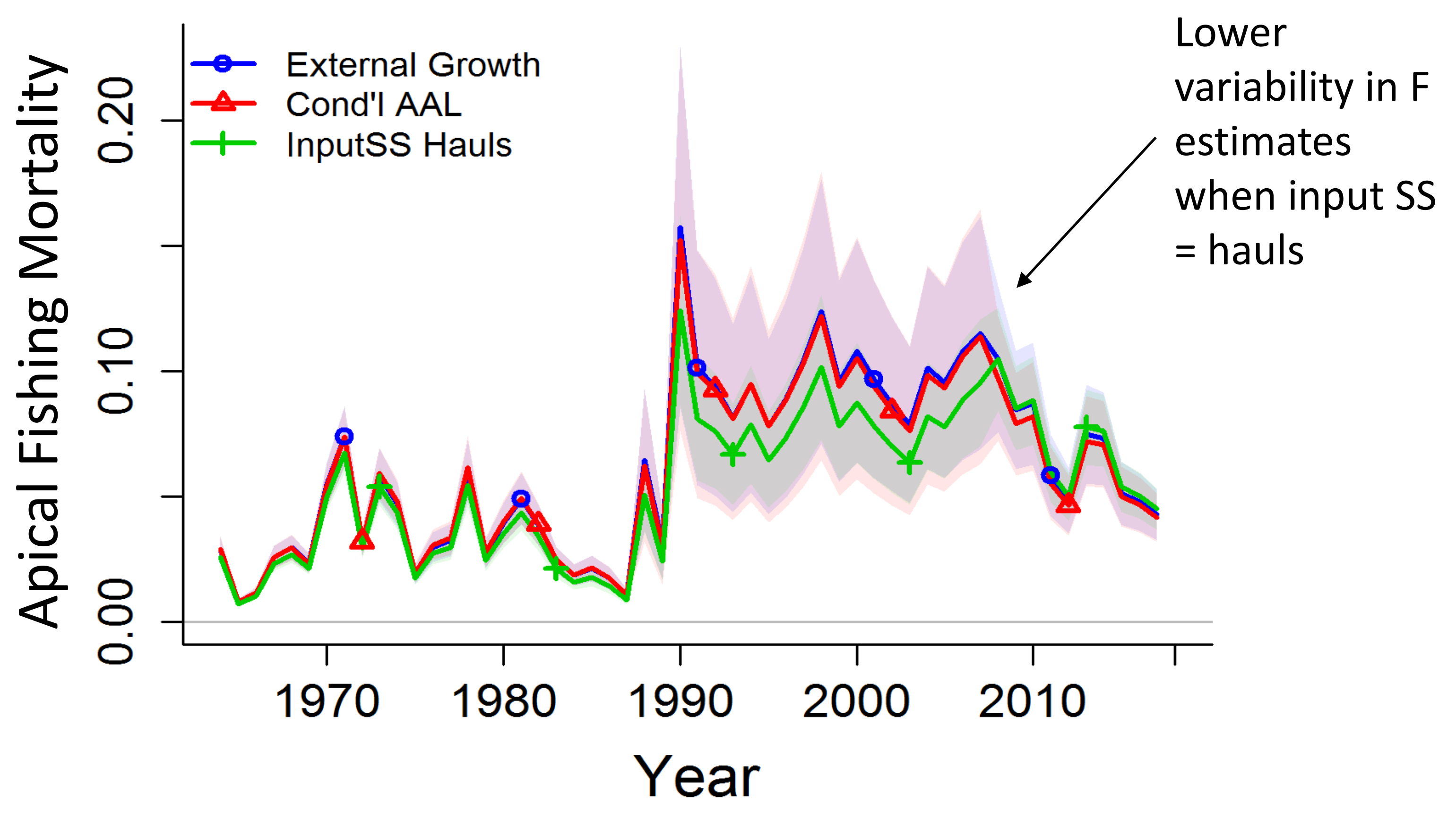




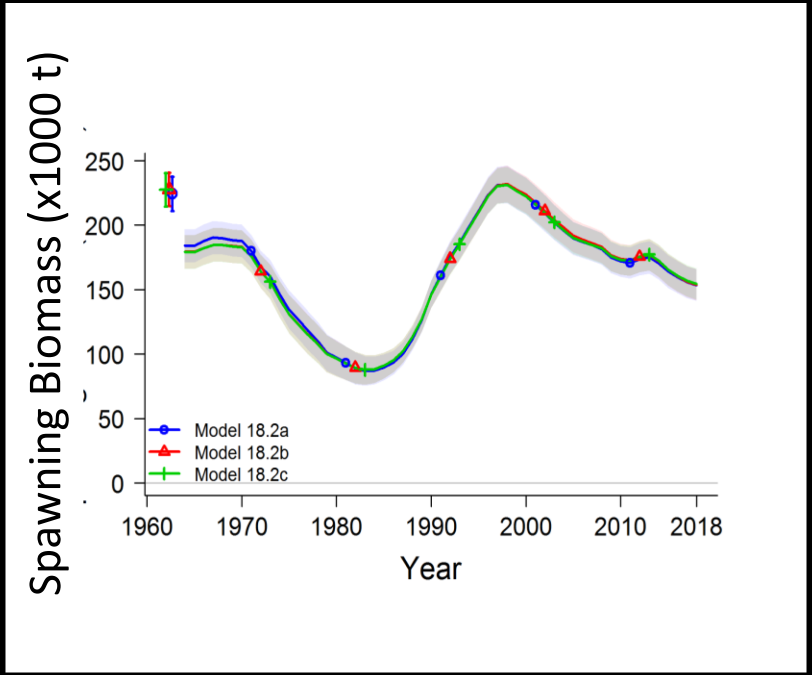


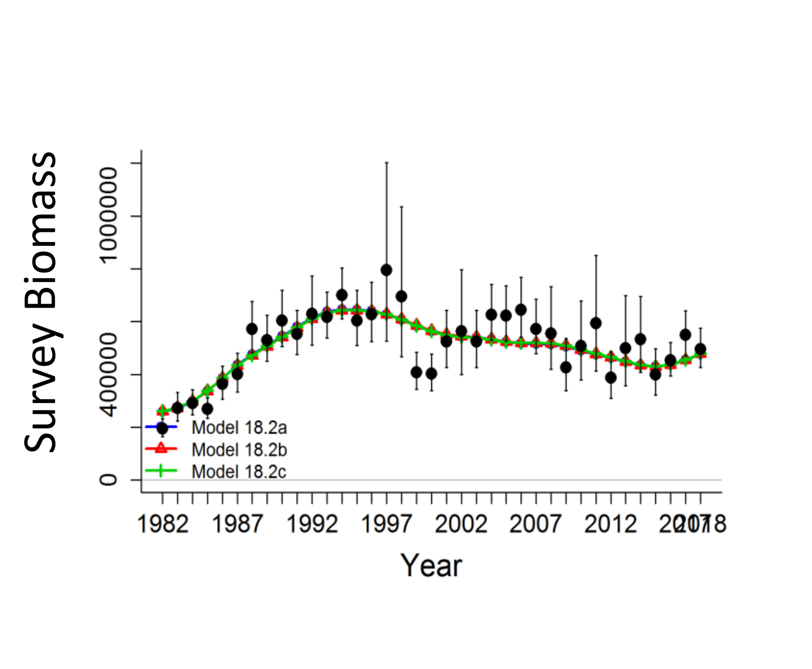


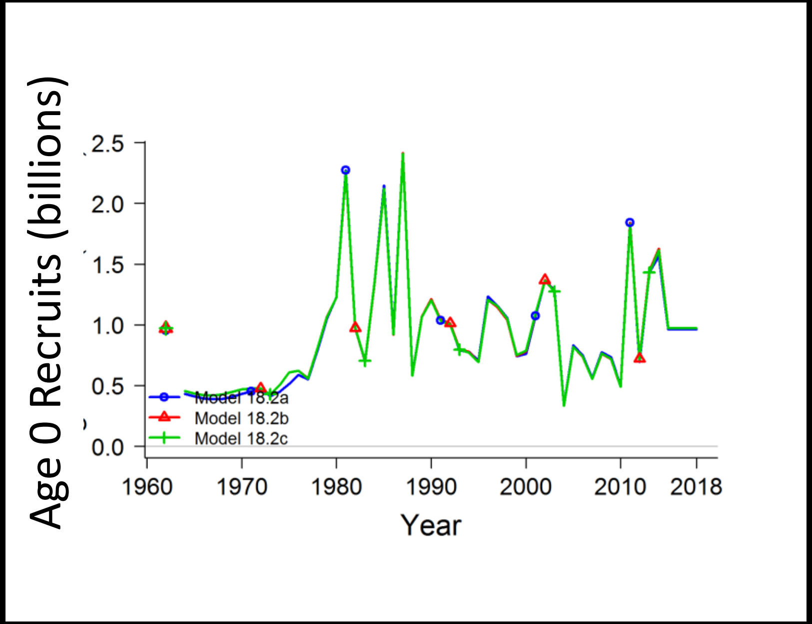
Comparing Models 18.0b, 18.1b, and 18.2b, continued

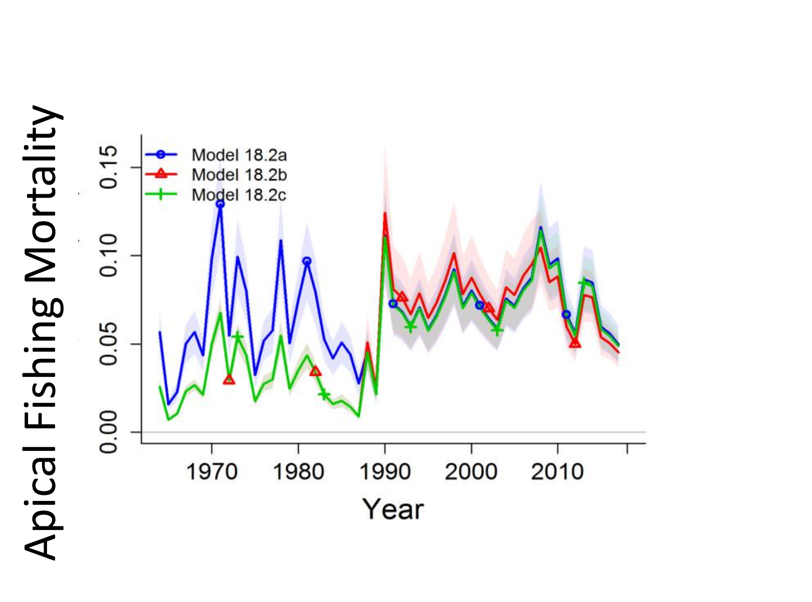


Comparing Models 18.2, 18.2b, and 18.2c



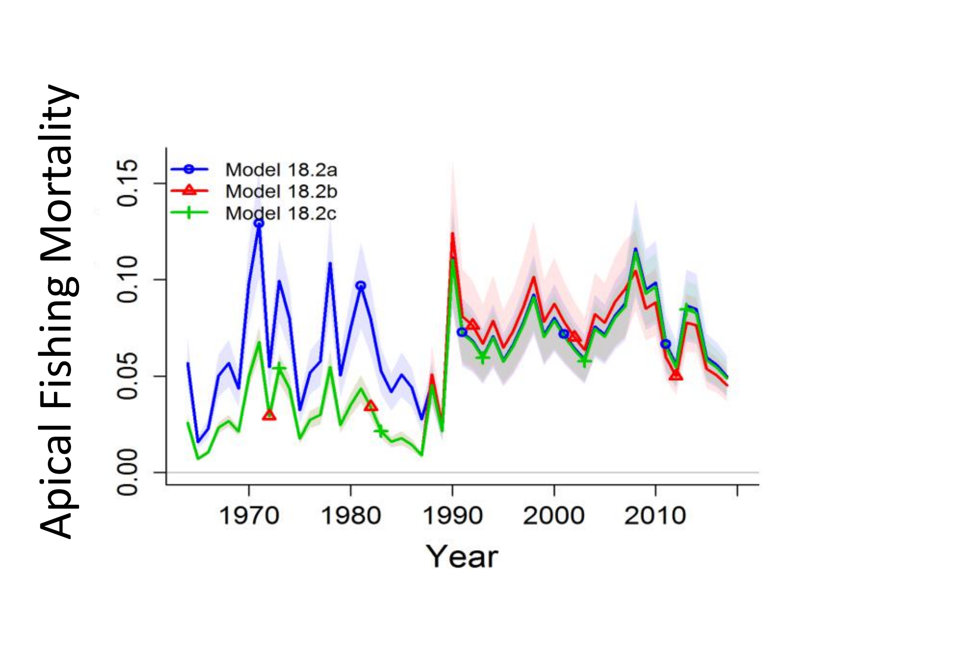




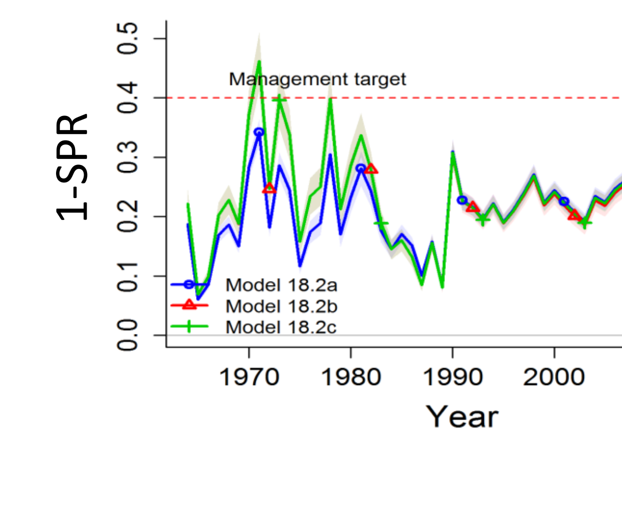


Comparing Models 18.2, 18.2b, and 18.2c

- 18.2 and 18.2b,c are two different ways to account for the overall fishing intensity
- More similar than apical F plot would suggest
- Fits to fishery length comp data are much better with 18.2b,c

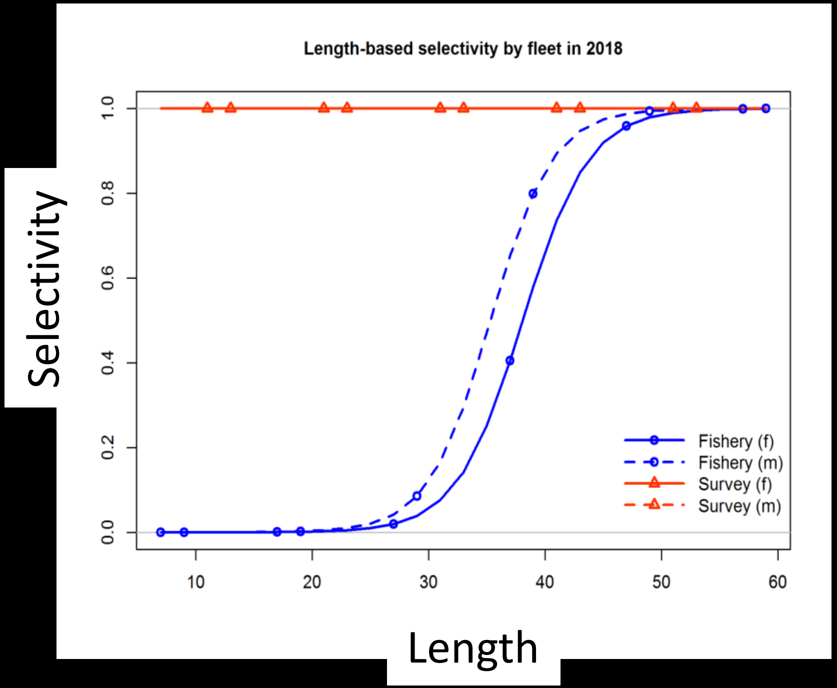


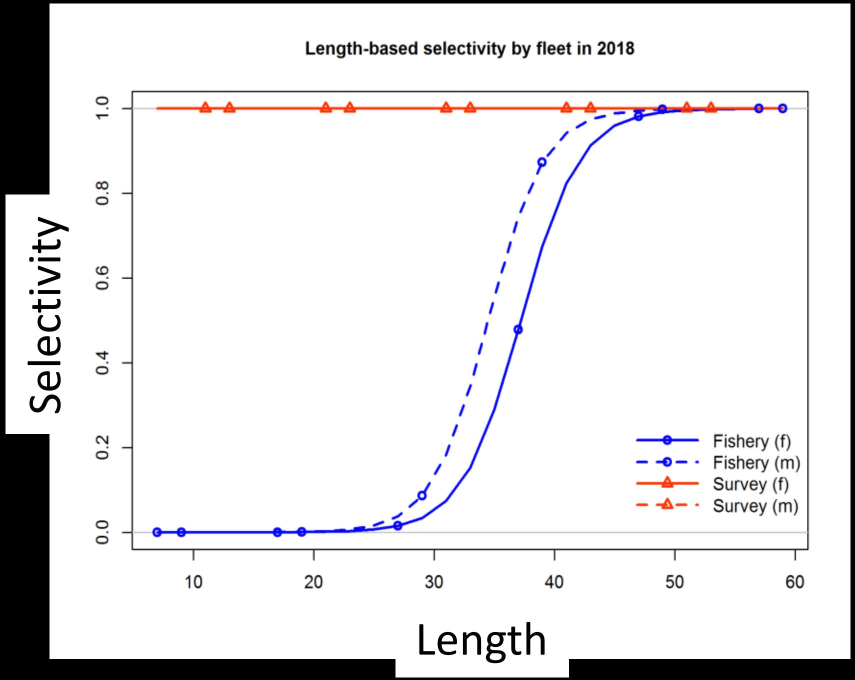
Ignore management target line

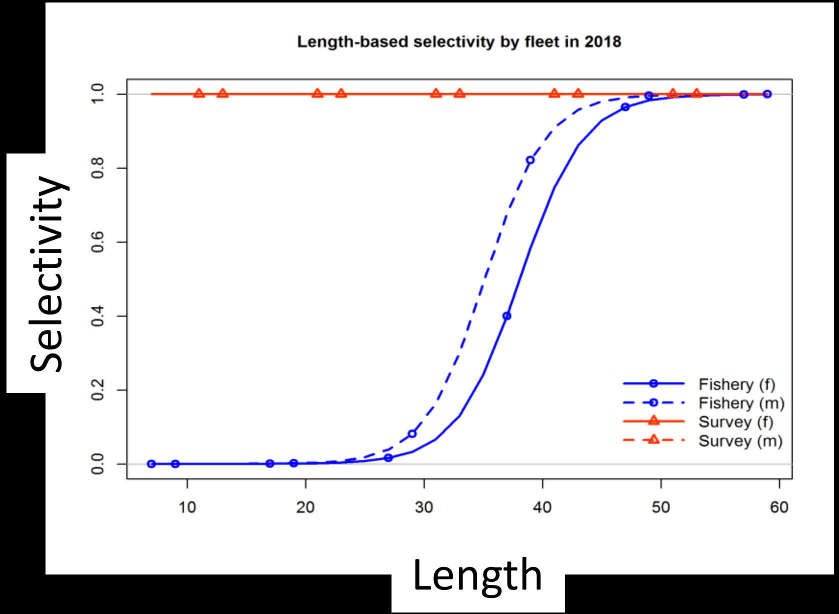


Comparing Models 18.2, 18.2b, and 18.2c

- Fishery selectivity in the most recent time period is very similar
- All models estimate male selex occurring at smaller lengths than female selex





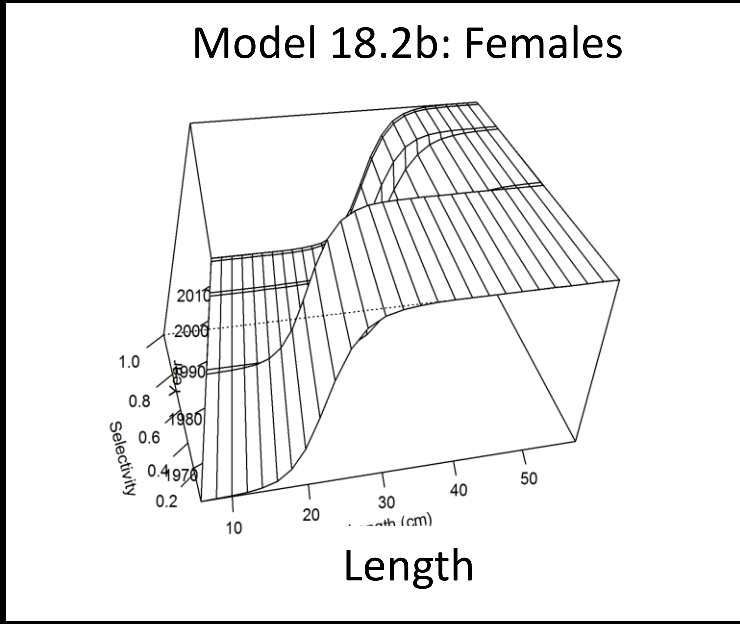


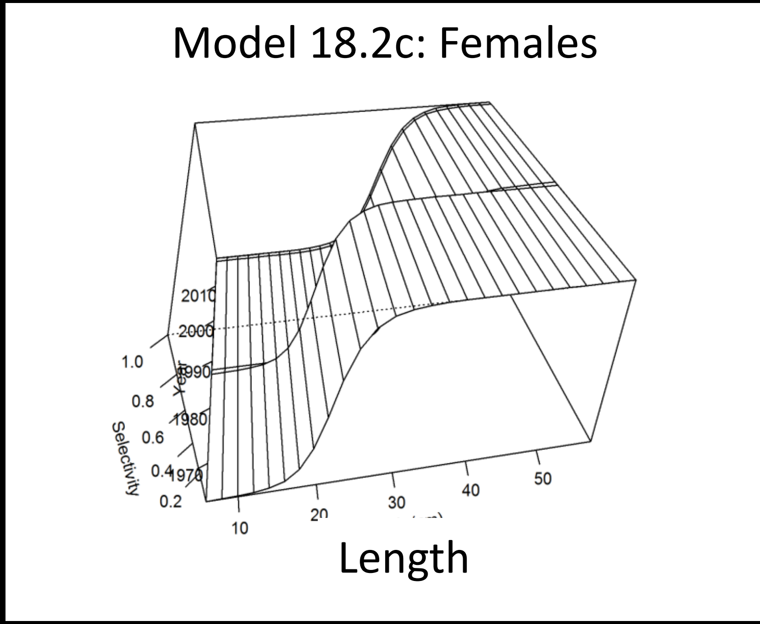
Why would males be caught at smaller lengths than females?

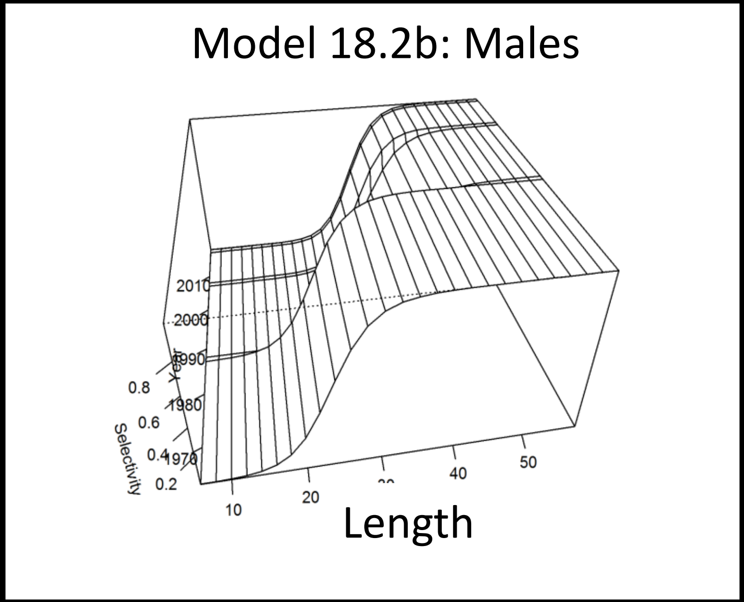
- Flathead organize by age groups such that is it more likely to catch similar ages together + males are smaller than females
  - Survey sampling group reported finding similar ages of flathead sole within hauls
  - Could be explored further by looking at the data at the haul level
- Bias in sexing – survey group does not think so. Flathead are relatively easy to sex

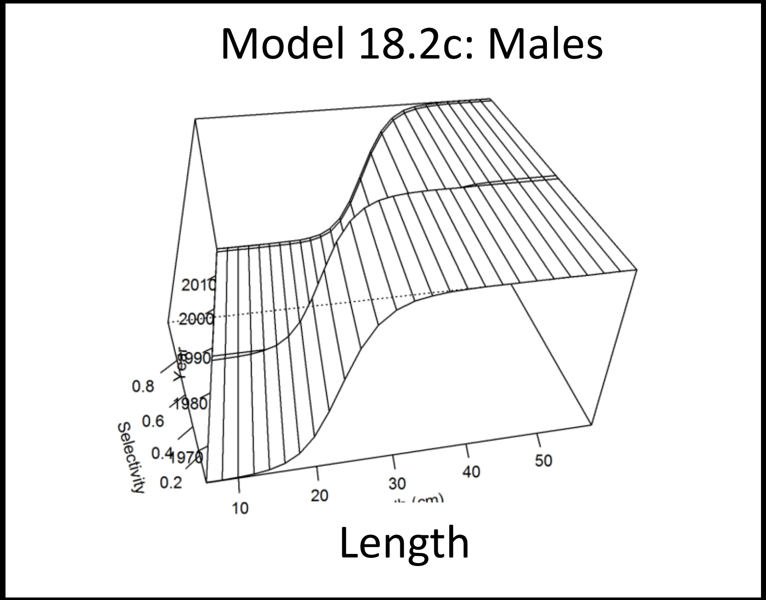
Comparing Models 18.2, 18.2b, and 18.2c

- Fishery selectivity through time. Models 18.2b and 18.2c estimate similar curves for the earliest time block (1964-1987)



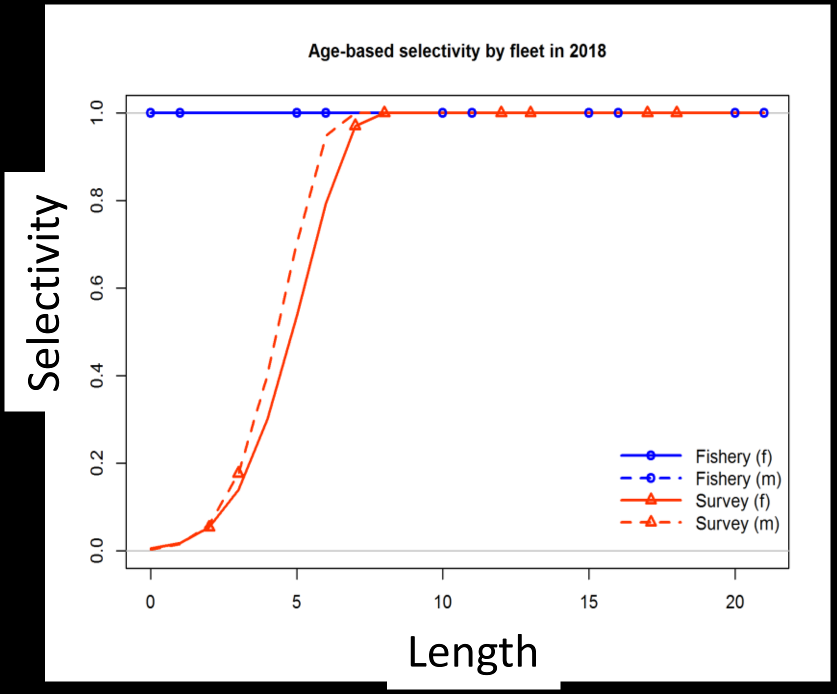


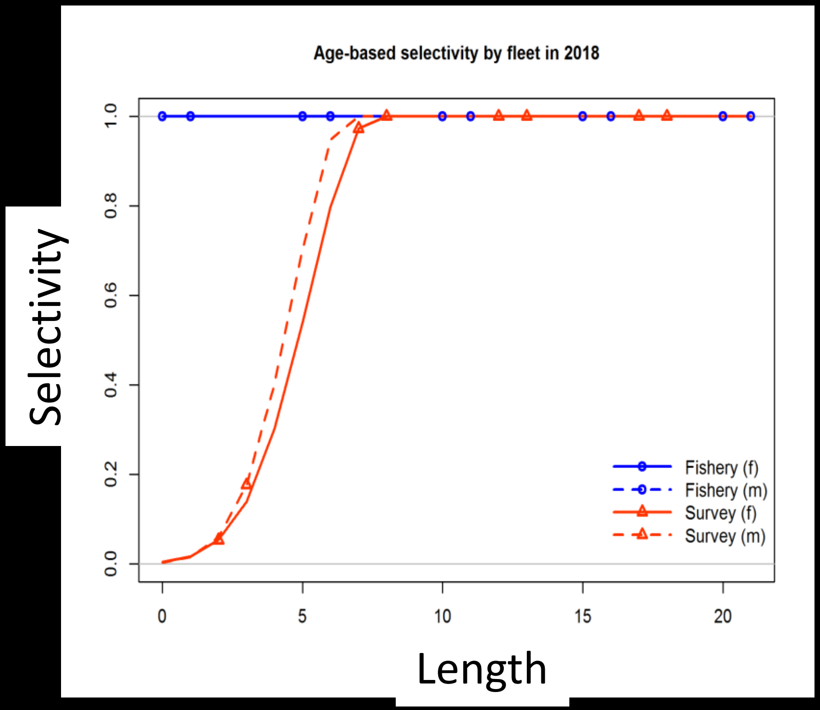


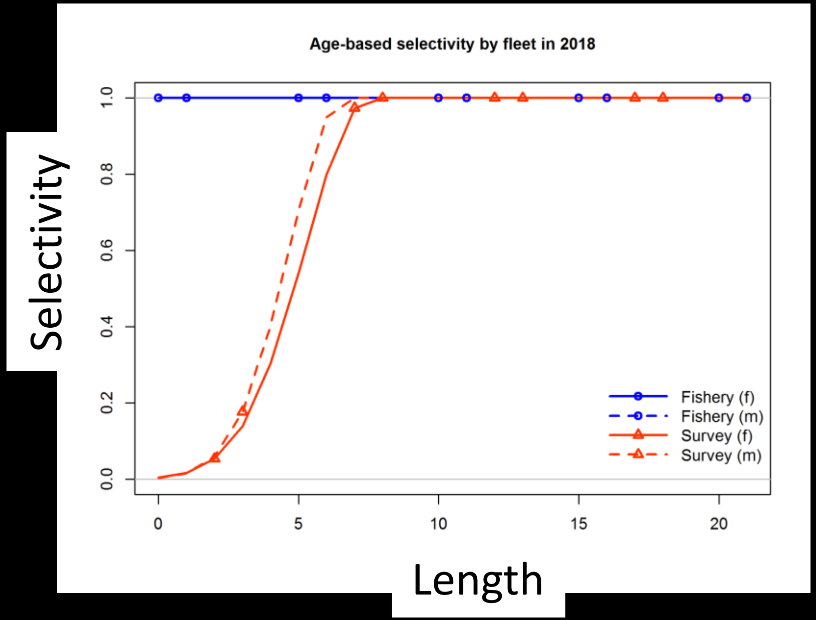


Comparing Models 18.2, 18.2b, and 18.2c

- Survey selectivity is very similar among the models

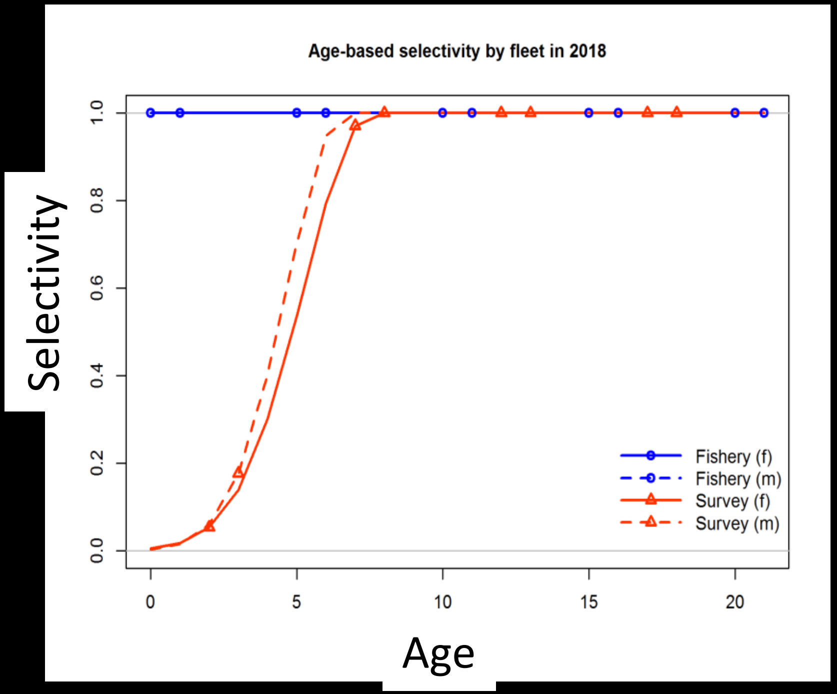


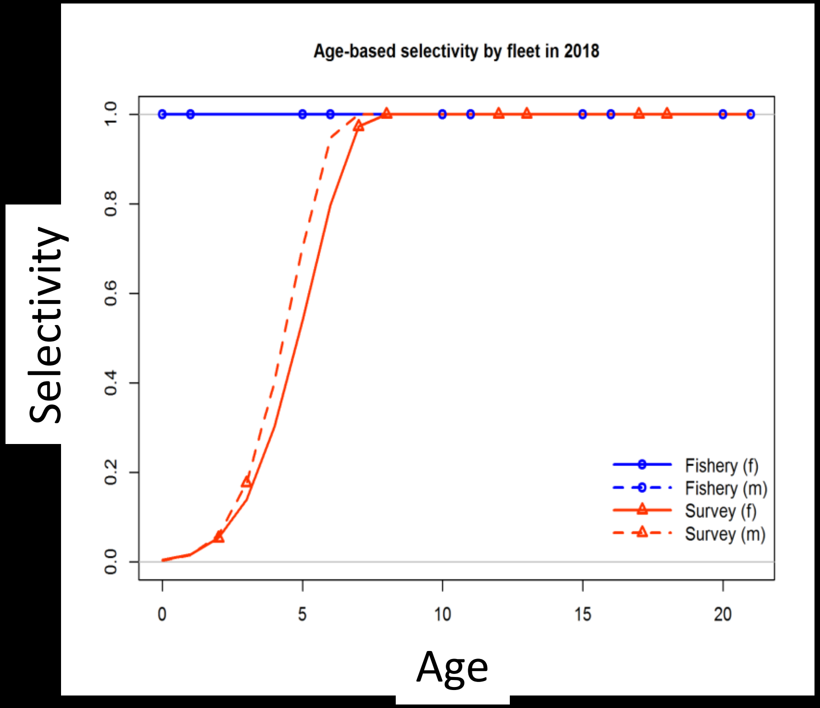


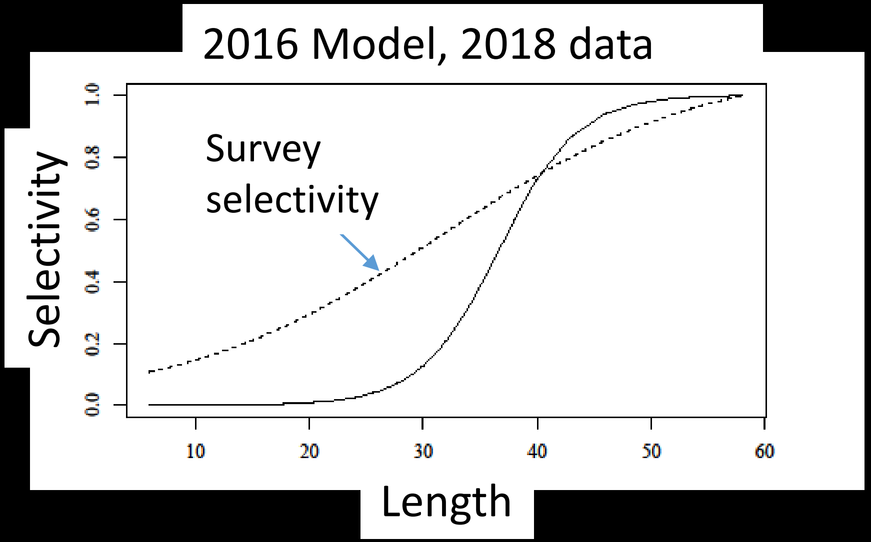


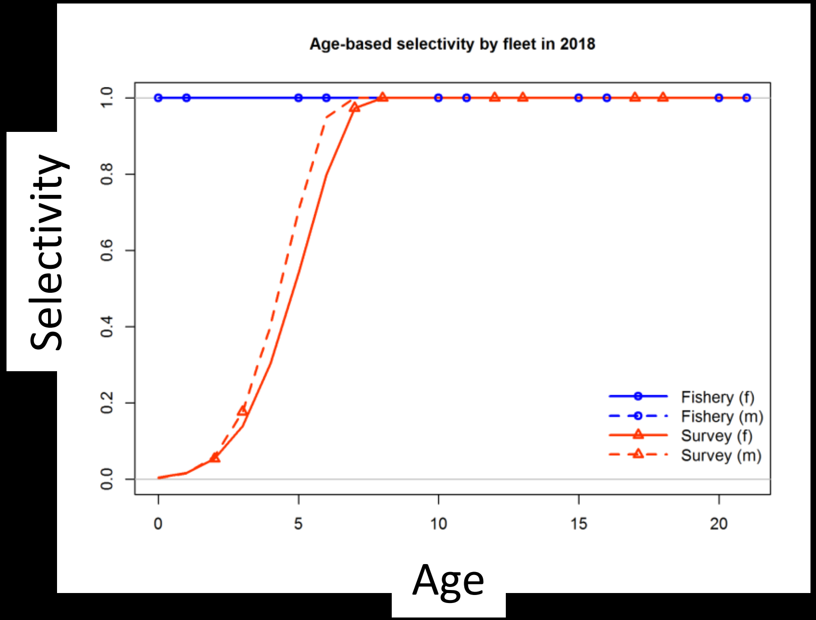
Comparing Models 18.2, 18.2b, and 18.2c

- Survey selectivity is very similar among the models
- Fixed the problematic survey selectivity from the 2016 model



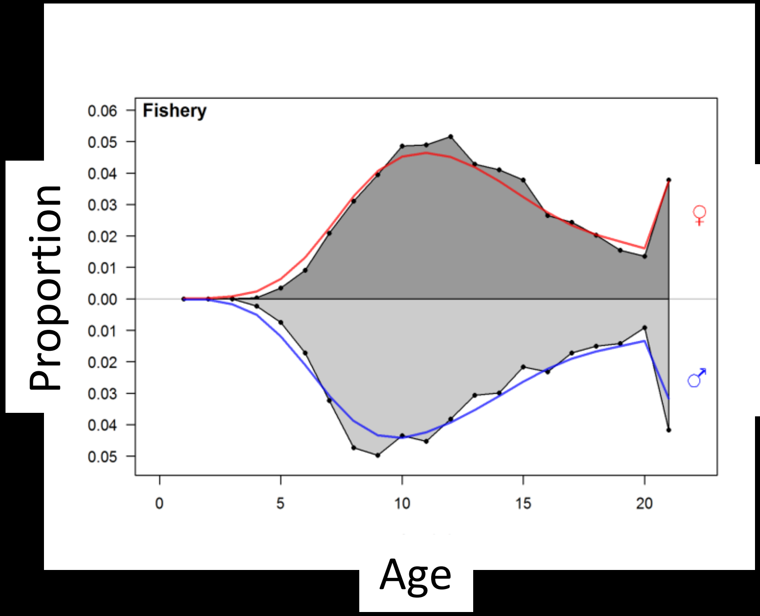


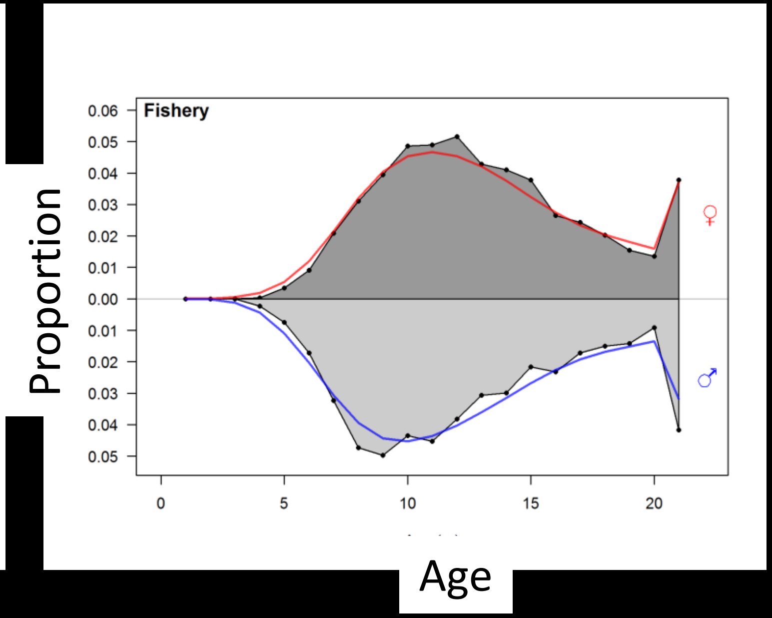


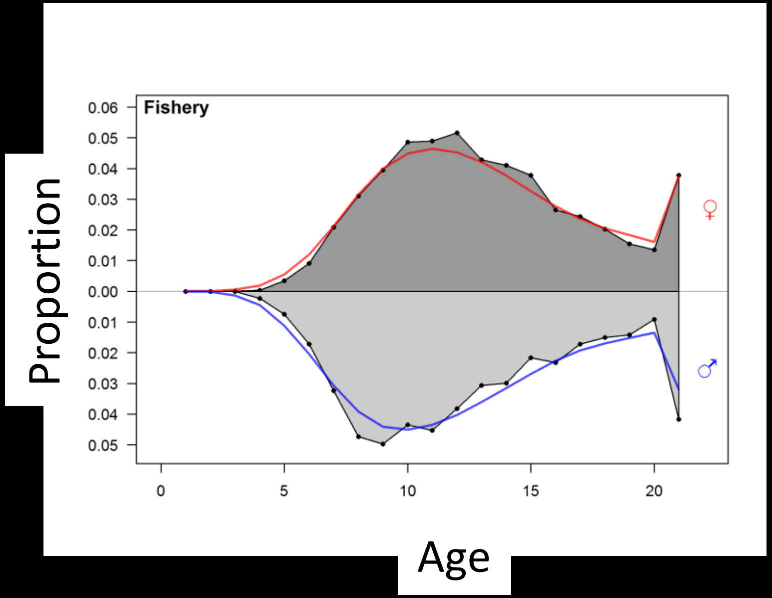


Comparing Models 18.2, 18.2b, and 18.2c

- Fits to fishery age comp data aggregated over years are similar
- Estimated growth parameters are very similar

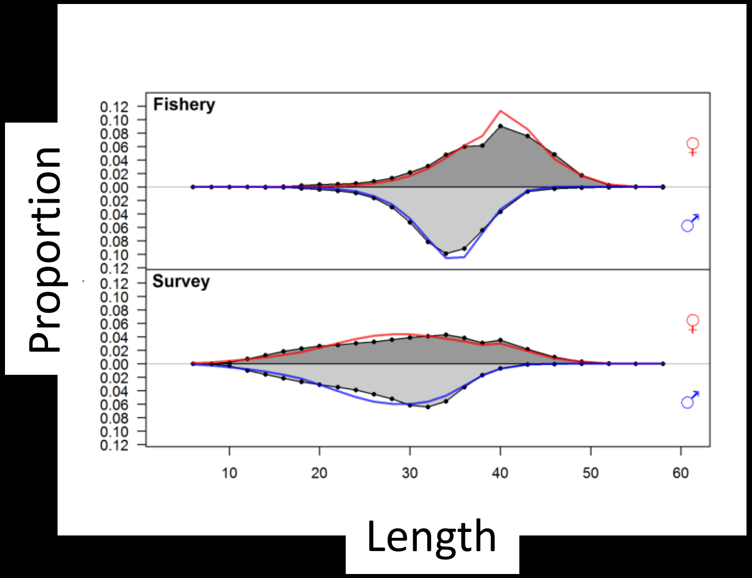


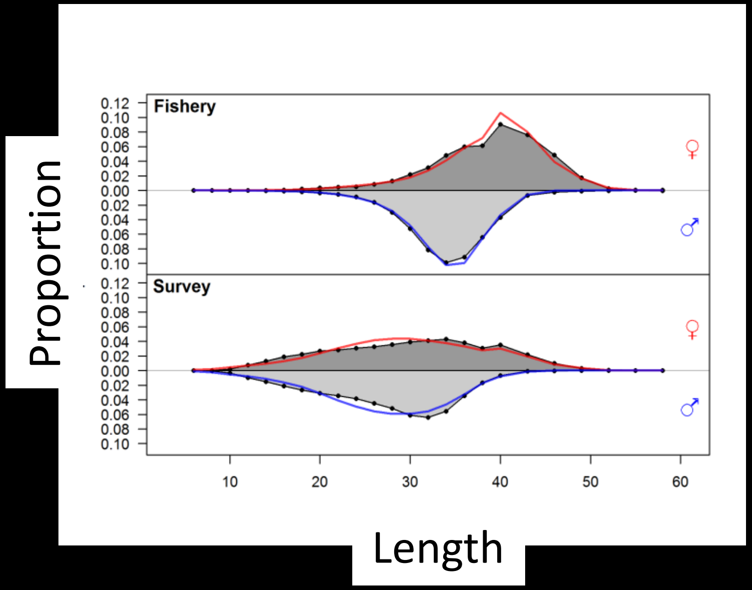


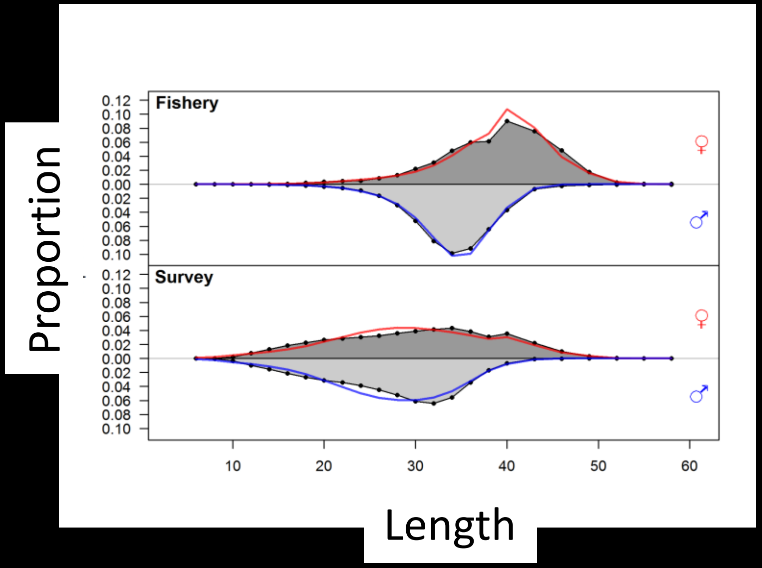


Comparing Models 18.2, 18.2b, and 18.2c

- Fits to length comp data aggregated over years are similar
- With input sample size = # of hauls, the early era is down-weighted substantially



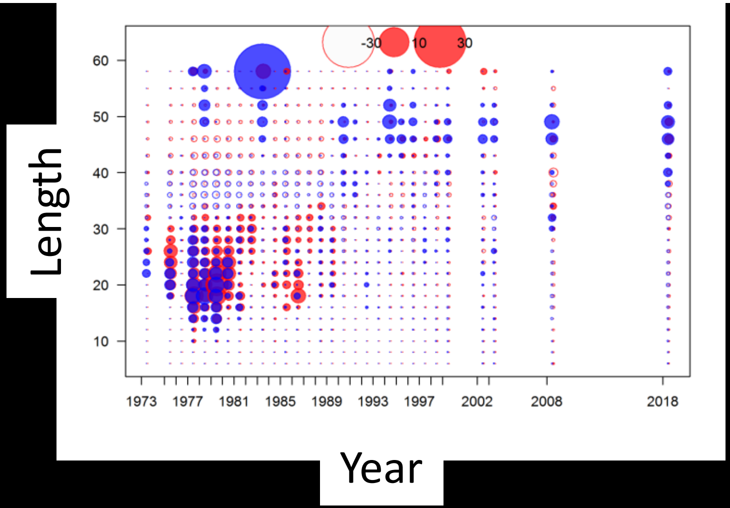




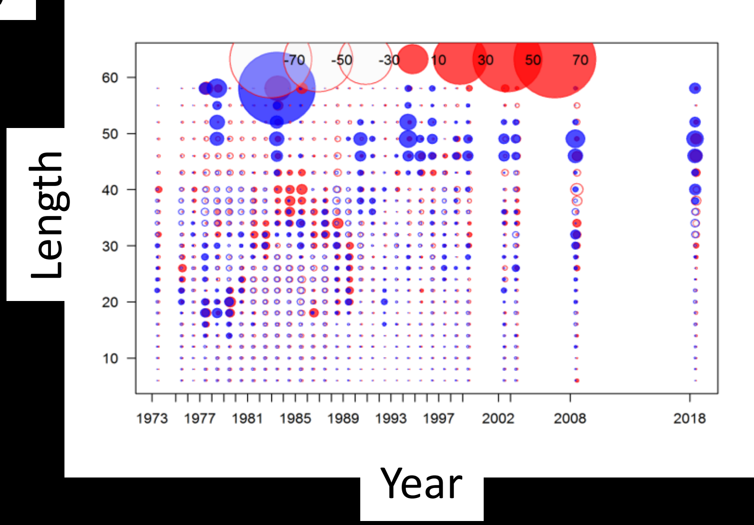
Comparing Models 18.2, 18.2b, and 18.2c

- Fits to fishery length comp in early era (1964-1987) is poor for Model 18.2 (time-invariant fishery selectivity) and much better if selex is estimated separately for this era
- Not much difference fits of the model to the data under 2 or 3 time eras for fishery selex

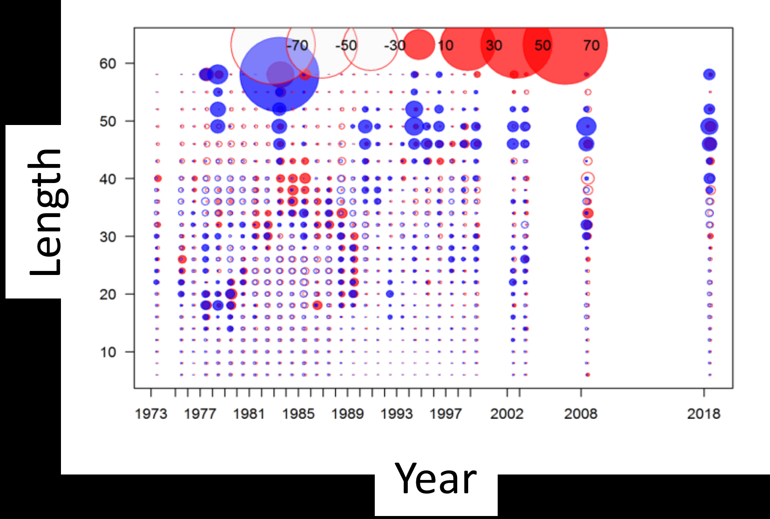
Model 18.2 (time invariant fish. Selex.)



Model 18.2b (3 fish. Selex eras)



Model 18.2c (2 fish. Selex eras)



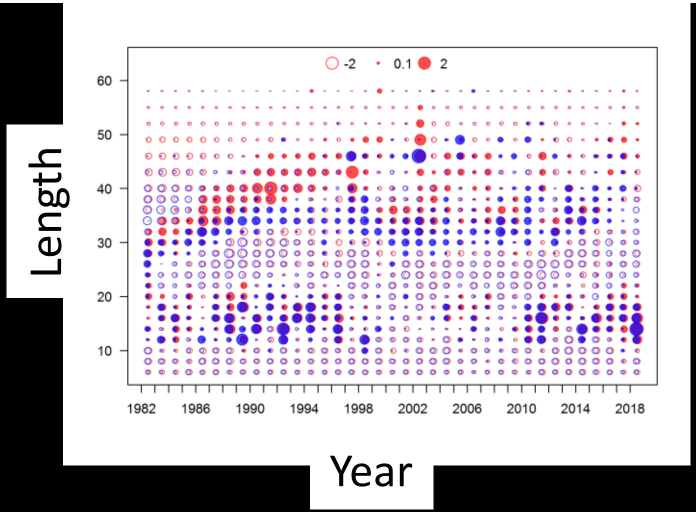
Could the fishery selectivity for 1964-1987 be different for some reason other than differences in selectivity?

- Doesn’t seem like it
- Ghost fishery length comp fits are very good, indicating no mismatch in length-at-age between survey and fishery data
- No major changes in length-at-age over time in plots of the survey data

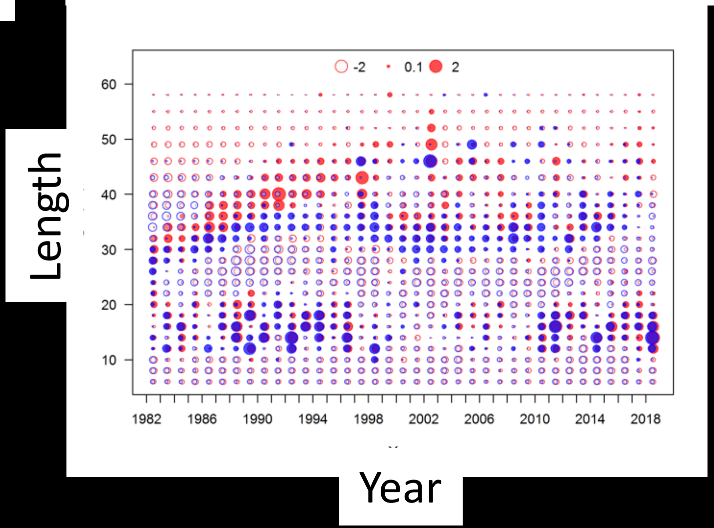
Comparing Models 18.2, 18.2b, and 18.2c

- Fits to survey length comp: Pearson residuals are small (+-2)
- However, there is a persistent pattern over time; several hypotheses were formulated and tested to see if could resolve the pattern. No.

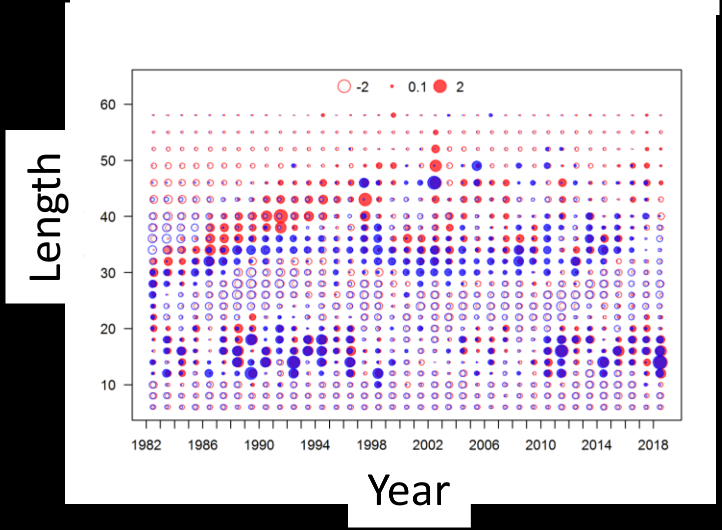
Model 18.2 (time invariant fish. Selex.)



Model 18.2b (3 fish. Selex eras)



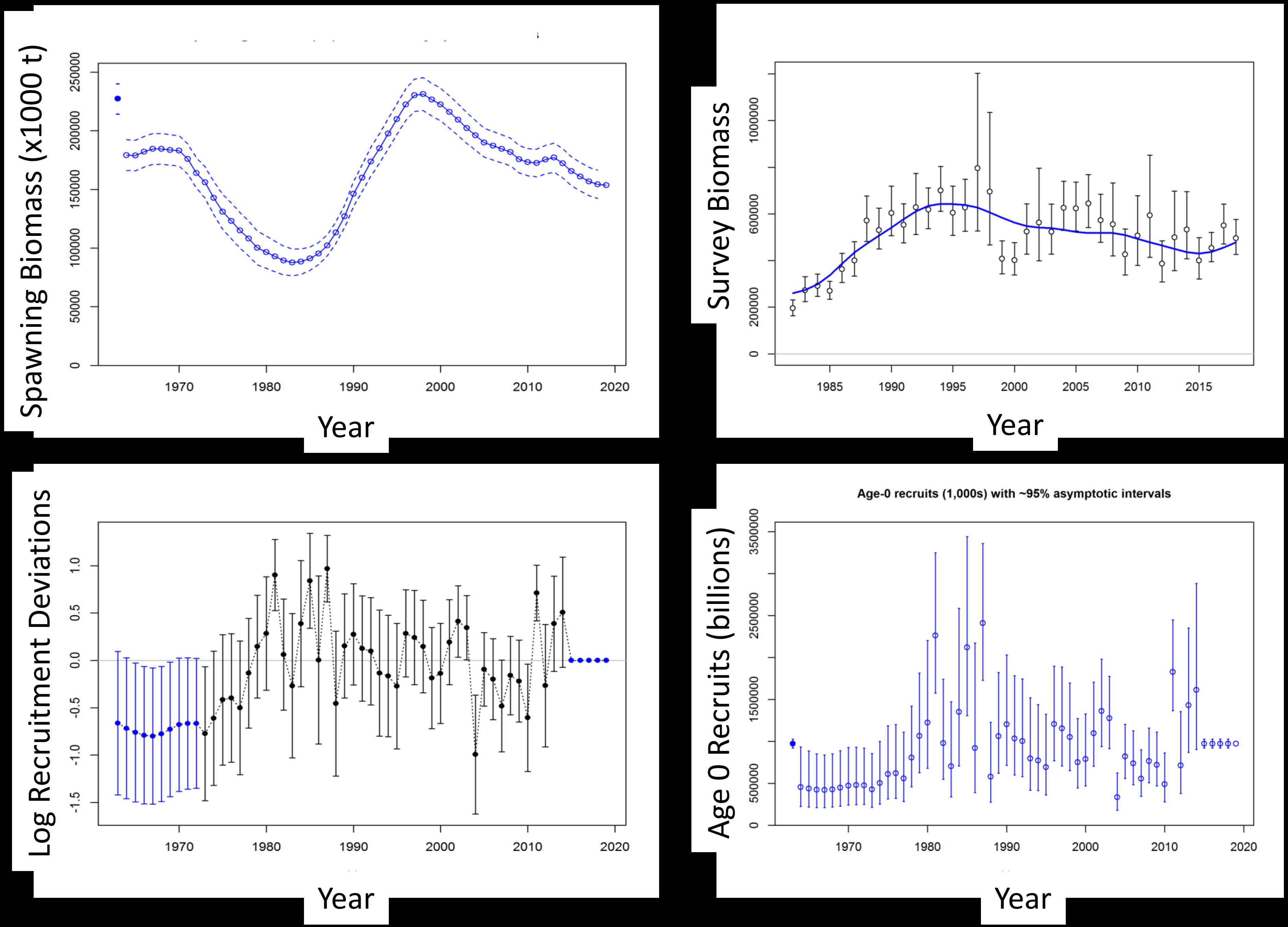
Model 18.2c (2 fish. Selex eras)



Hypotheses about small, persistent residual pattern:

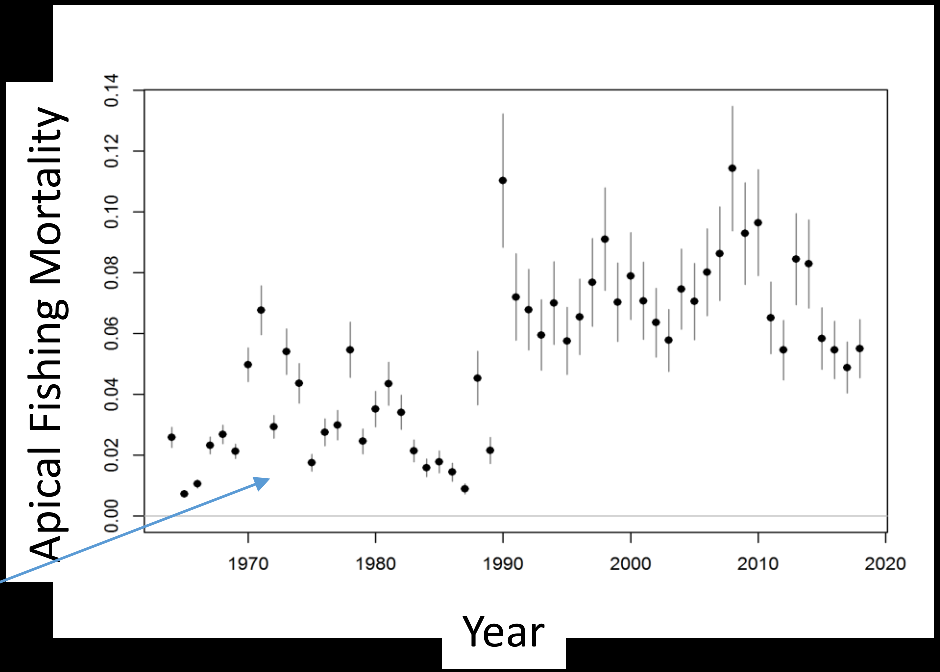
- Shape of survey selectivity curve too constraining
- Shape of von-Bertlanffy growth curve too constraining
- Variability in growth not adequately represented by CV in length-at-age 3 and 21+
- Conflict in the data between survey biomass and survey composition data
- Data don’t fully characterize variability in length-at-age for flathead sole (not enough ages??)

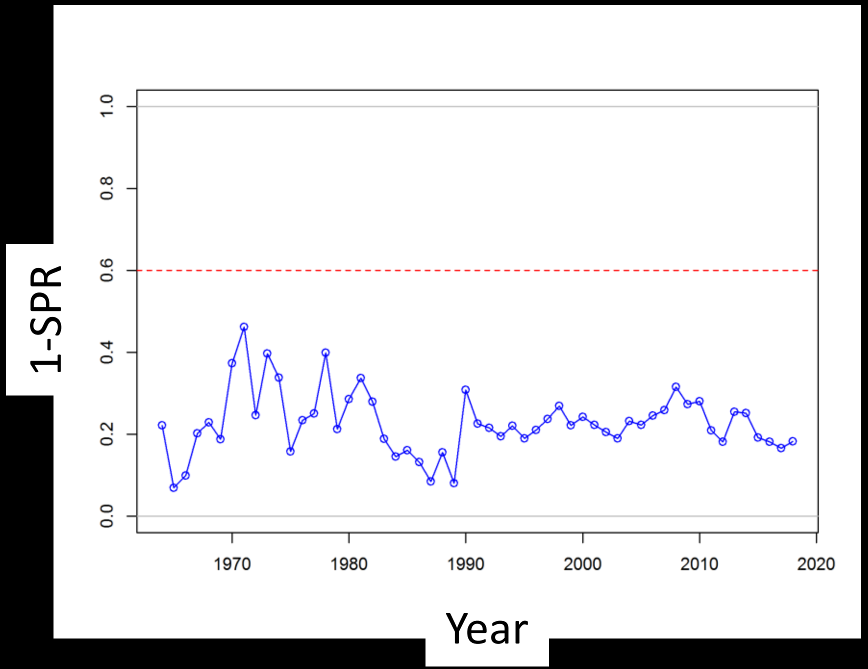
Model 18.2c results



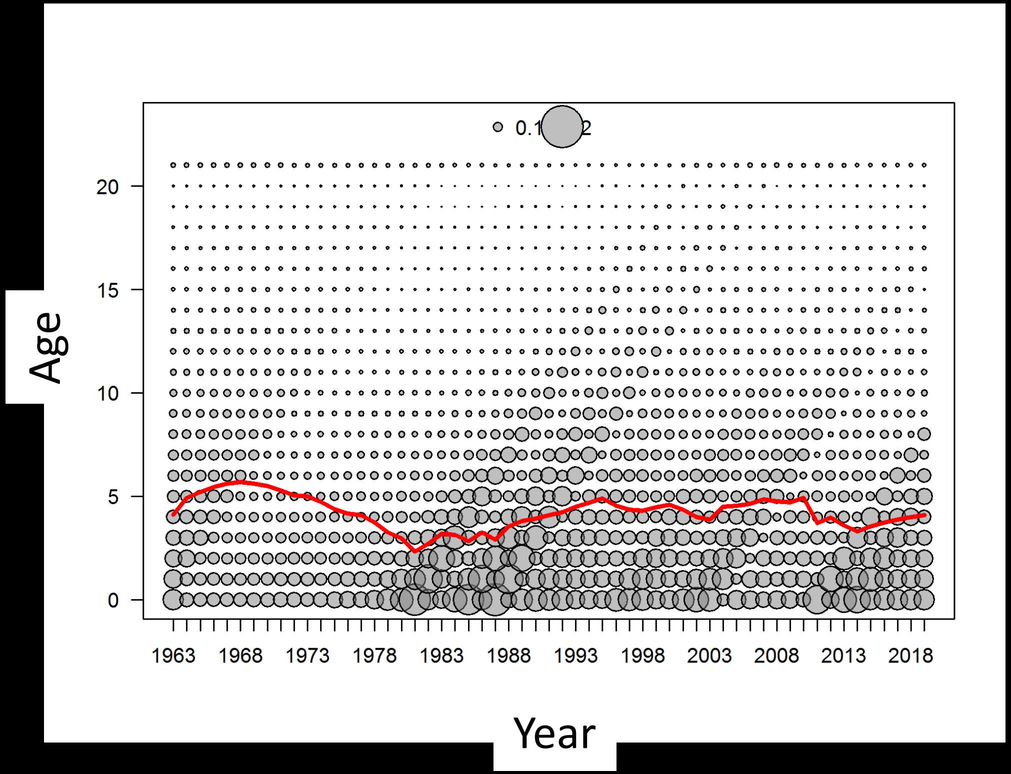
Model 18.2c results

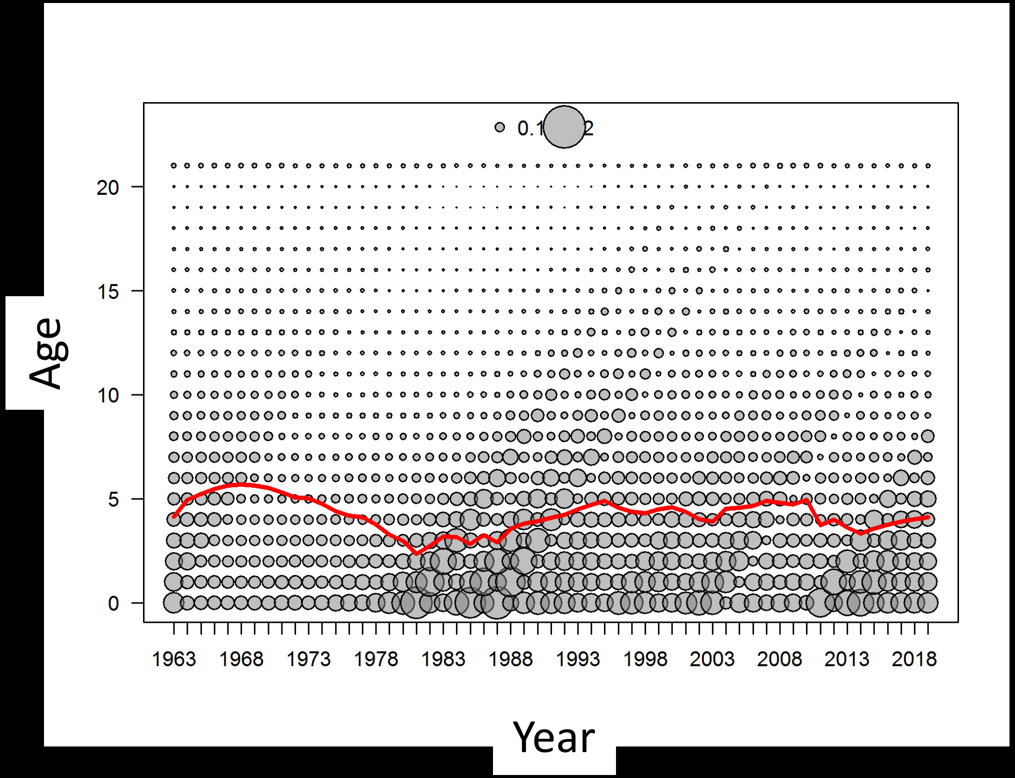
Early period fishery selectivity occurs at substantially smaller lengths than post-1988 fishery selectivity



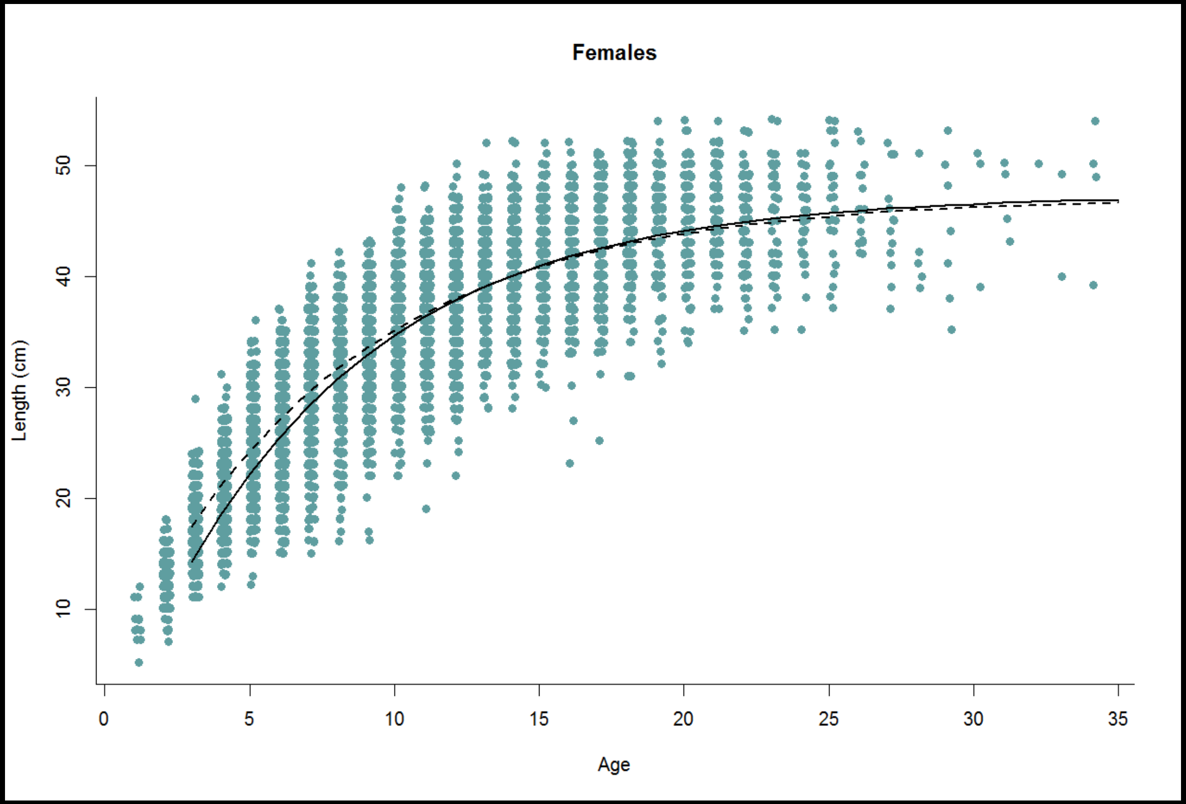


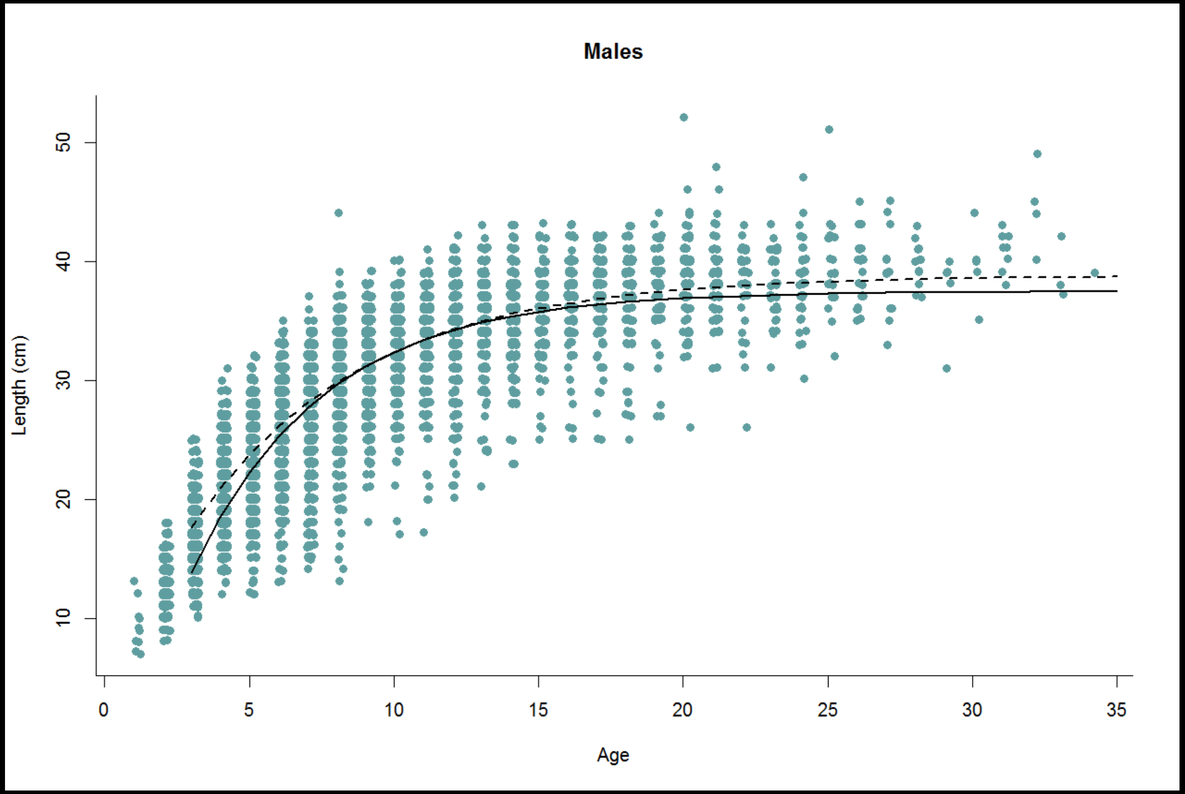
Model 18.2c: Estimated numbers-at-age



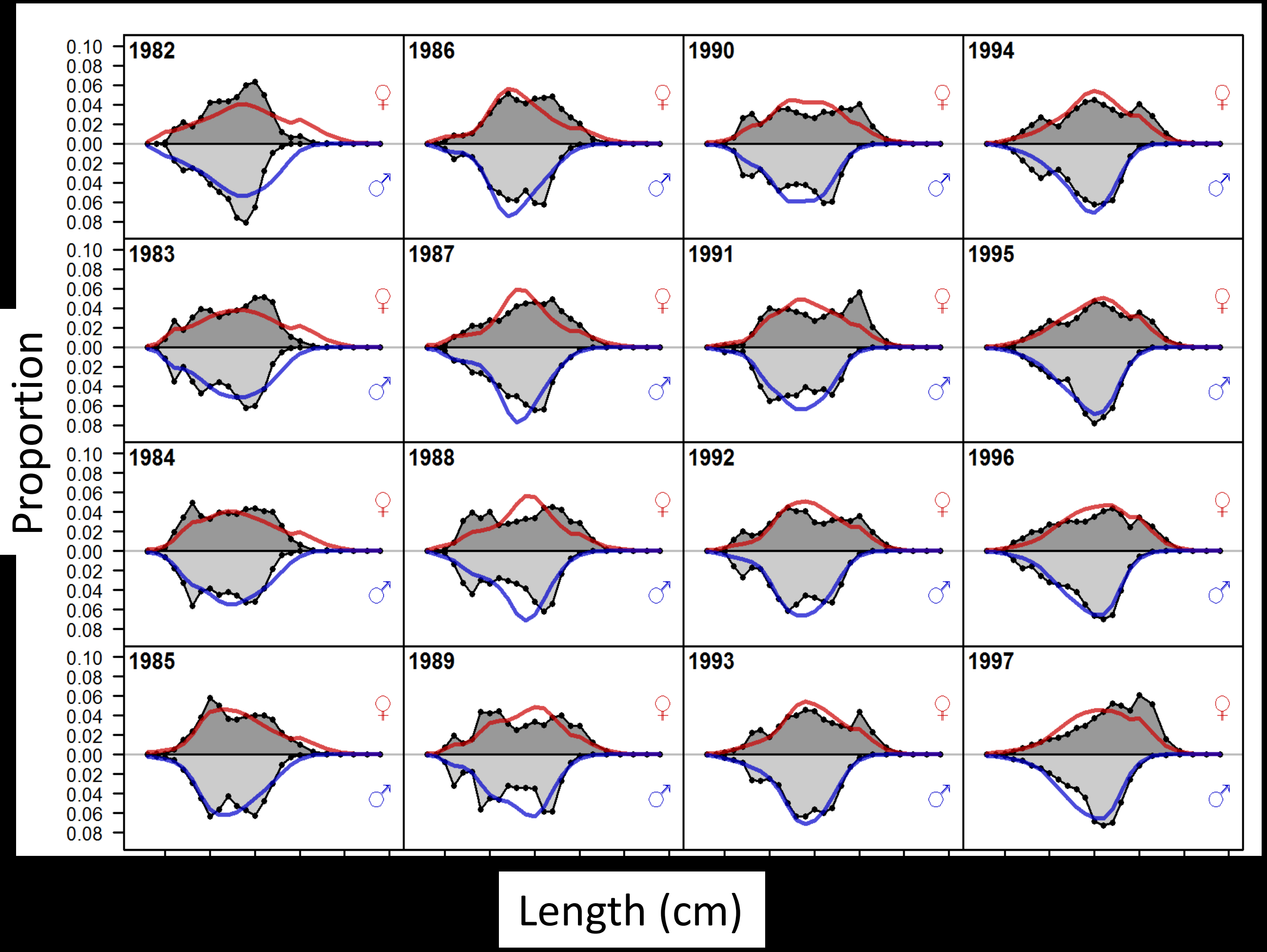


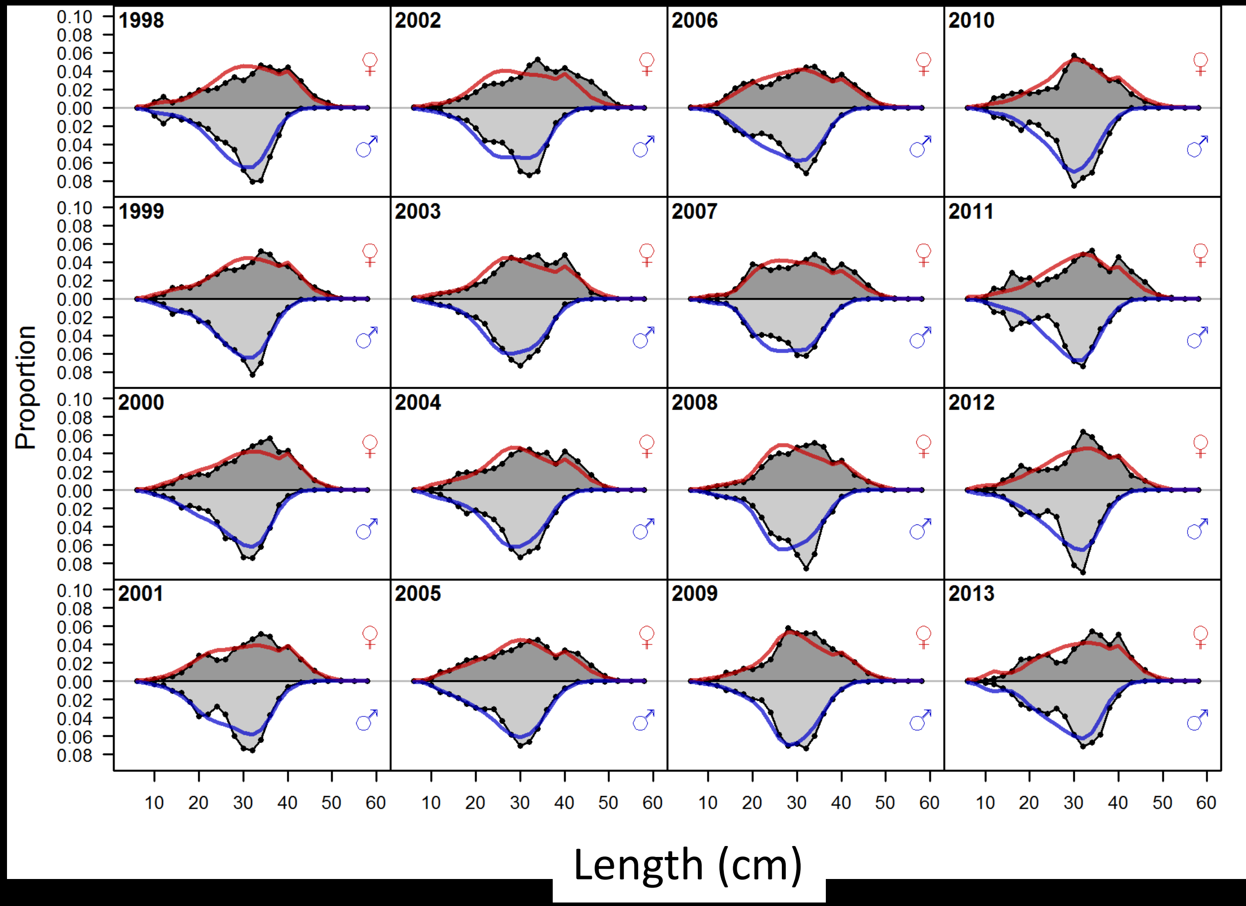
Model 18.2c: Estimates of growth



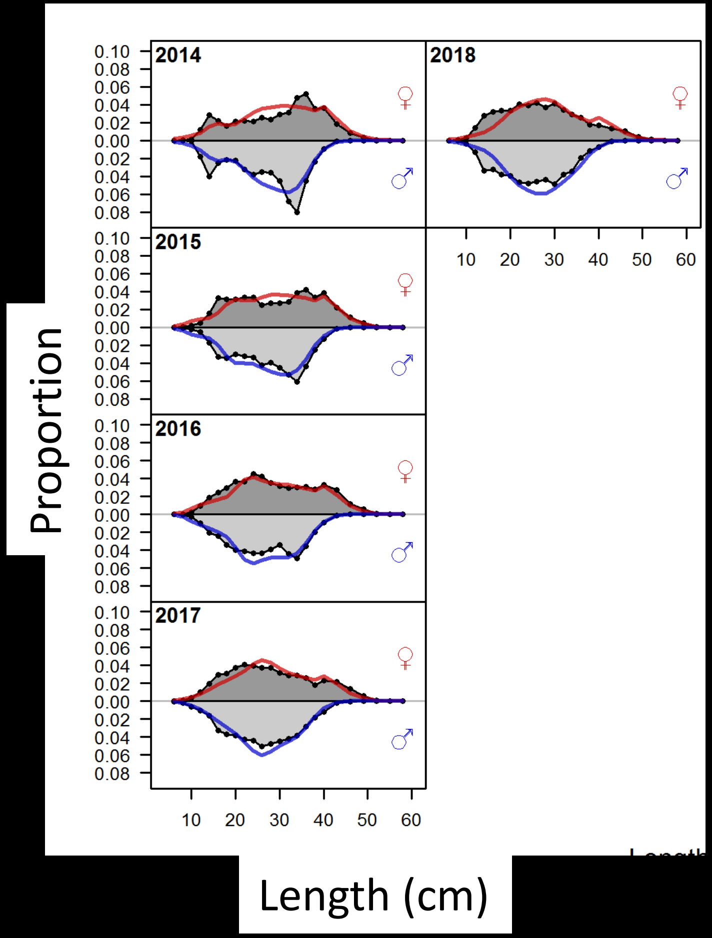


Model 18.2c: Fits to survey length composition





Model 18.2c: Fits to survey length composition

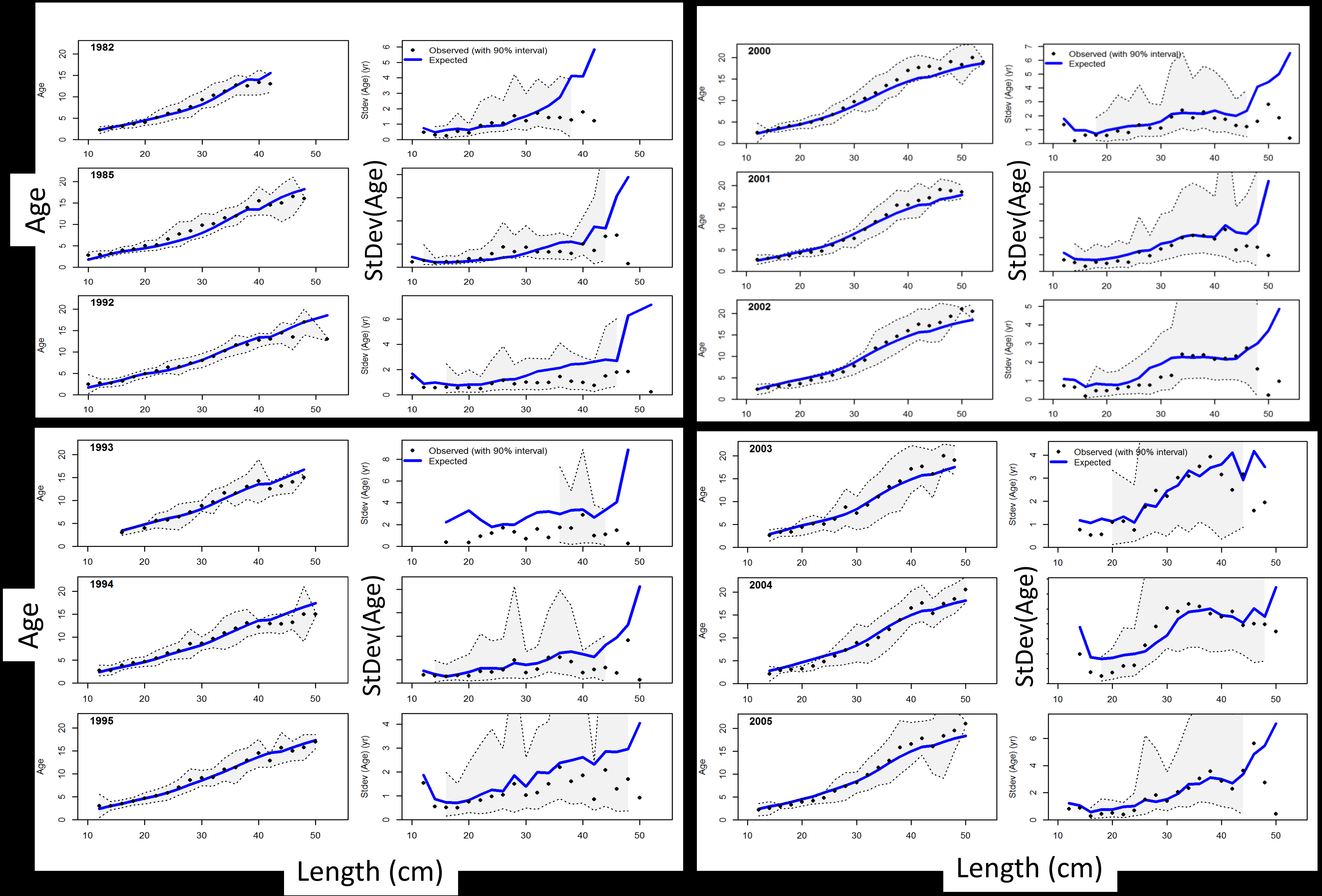


Model 18.2c:

Left columns: Observed and expected mean age-at-length for both females and males 90% intervals about observed age-at-length

Right columns: Observed and expected standard deviation in age-at-length

Aggregated over sex

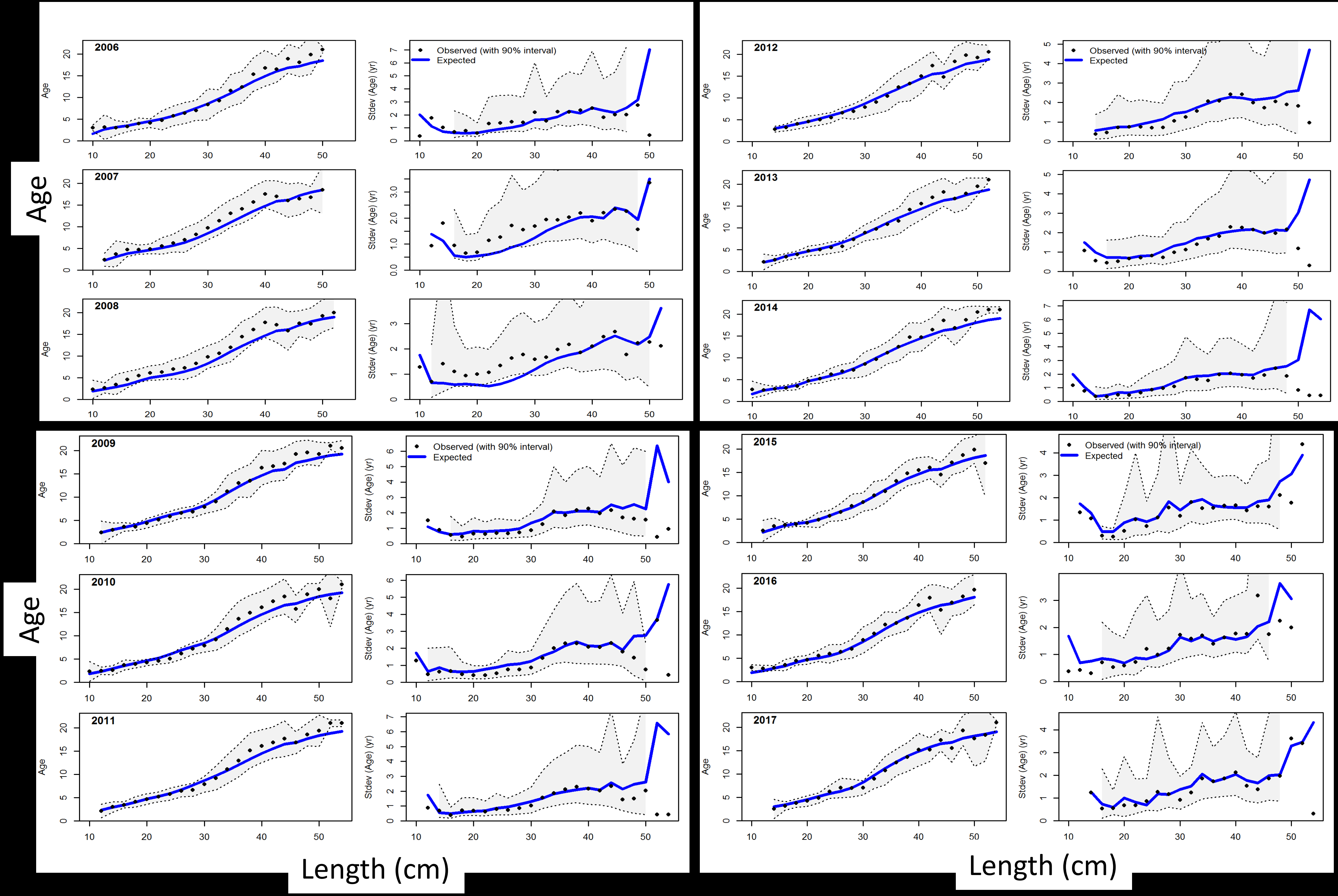


Model 18.2c:

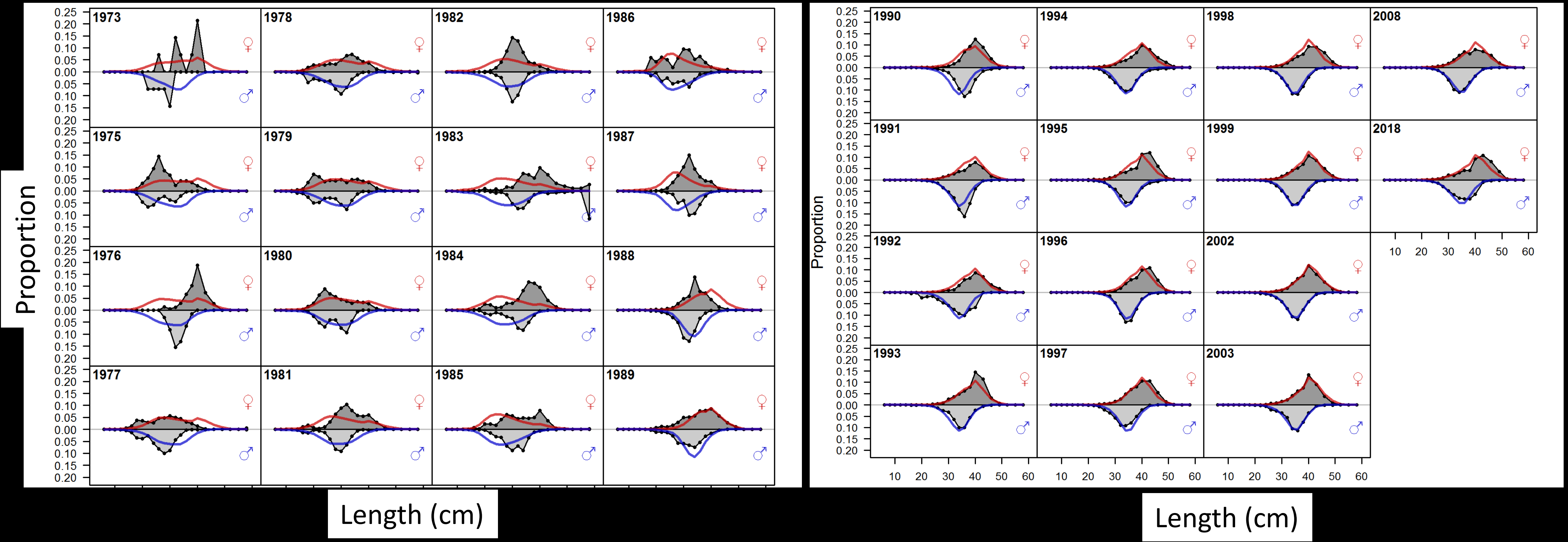
Left:
Observed and expected mean age-at-length for both females and males 90% intervals about observed age-at-length

Right:
Observed and expected standard deviation in age-at-length

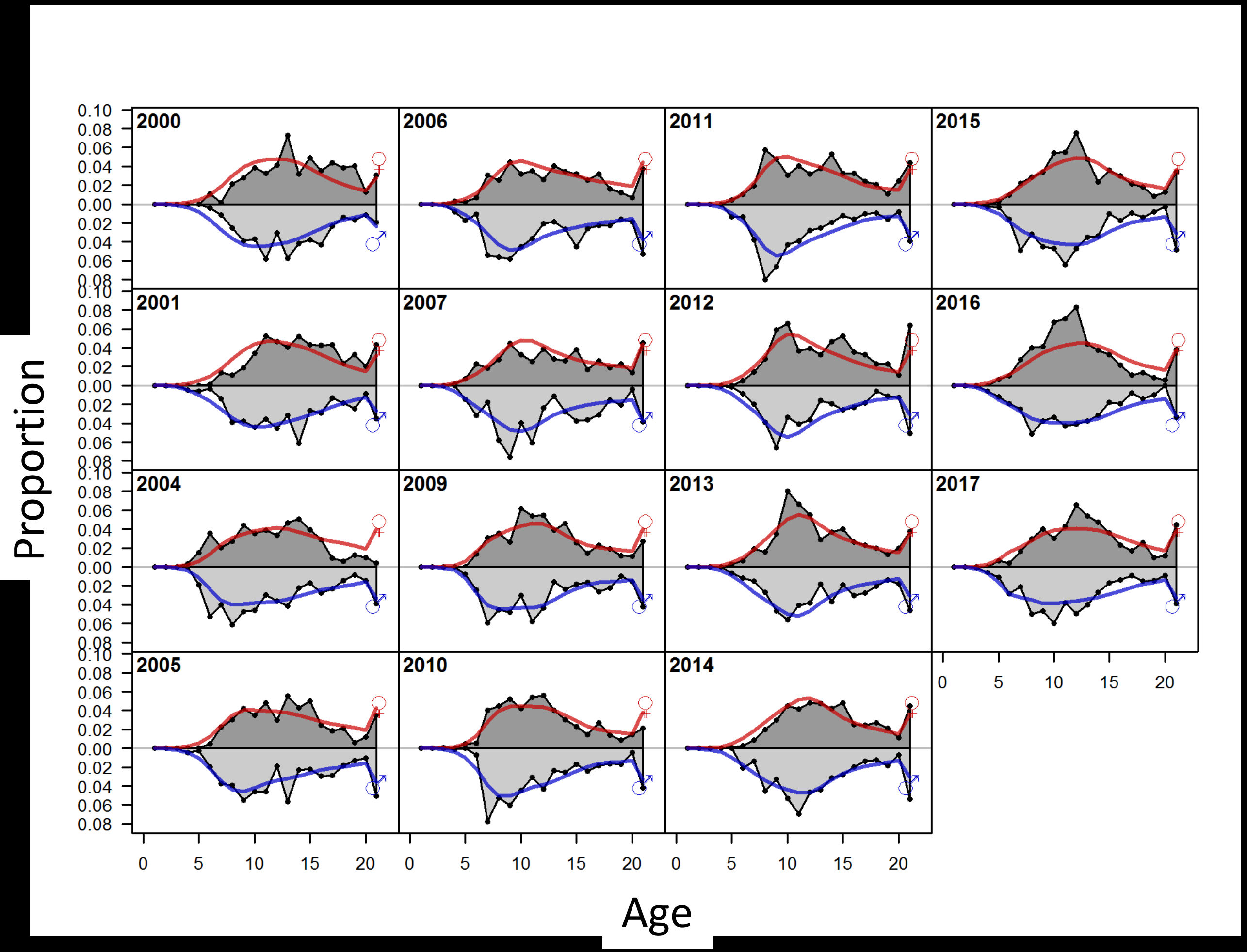
Aggregated over sex



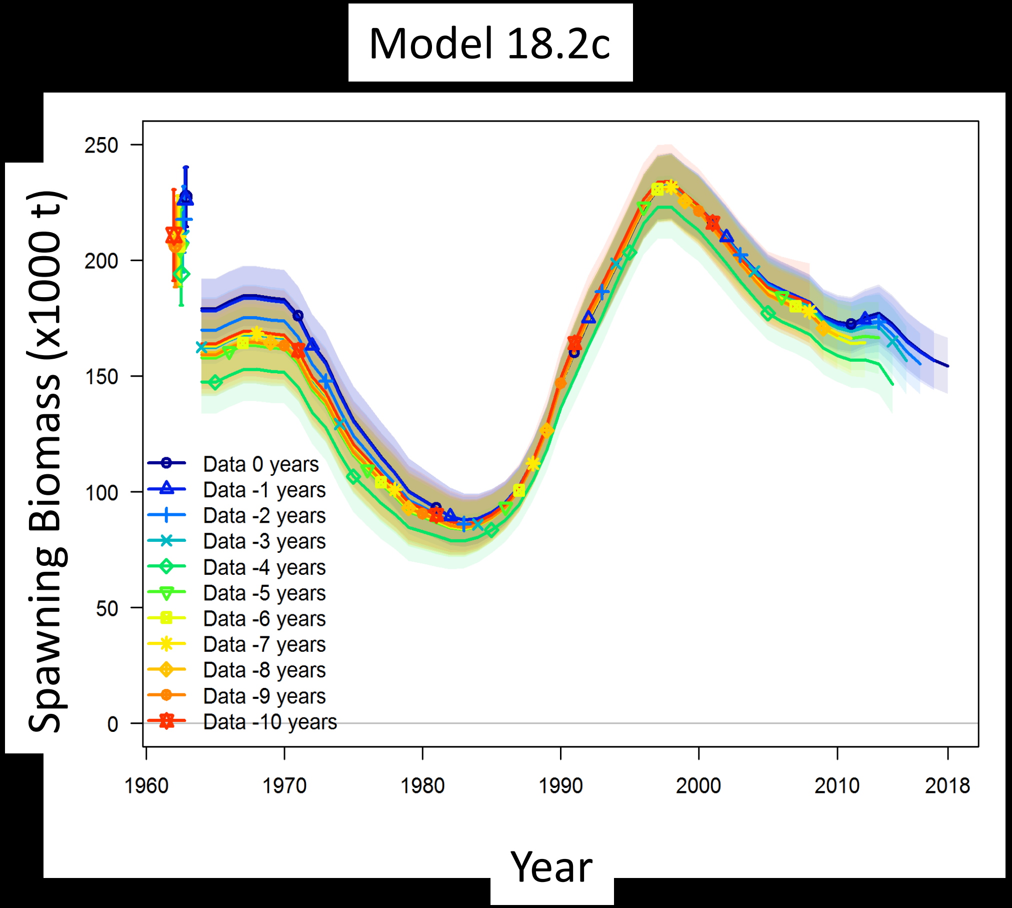
Model 18.2c: Fits to fishery length composition

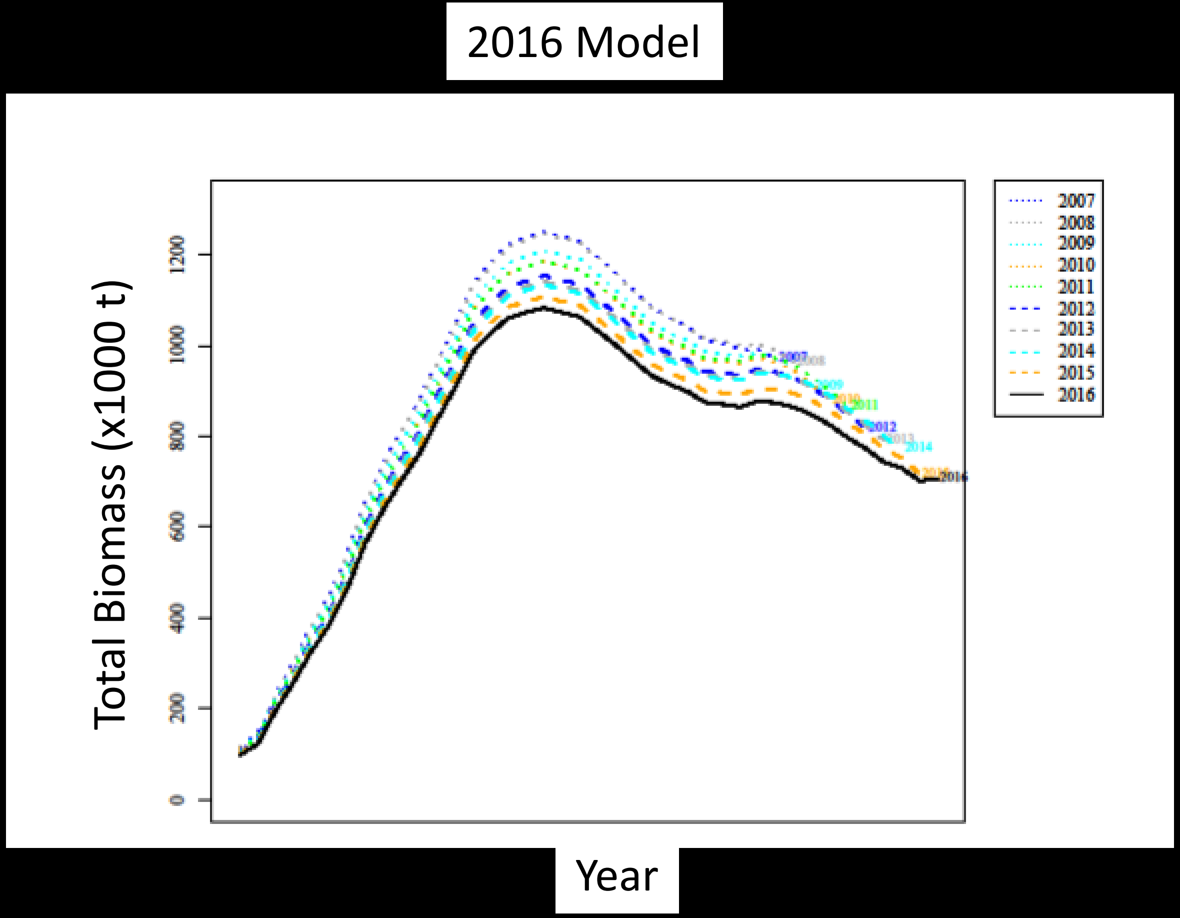


Model 18.2c: Fits to fishery age composition



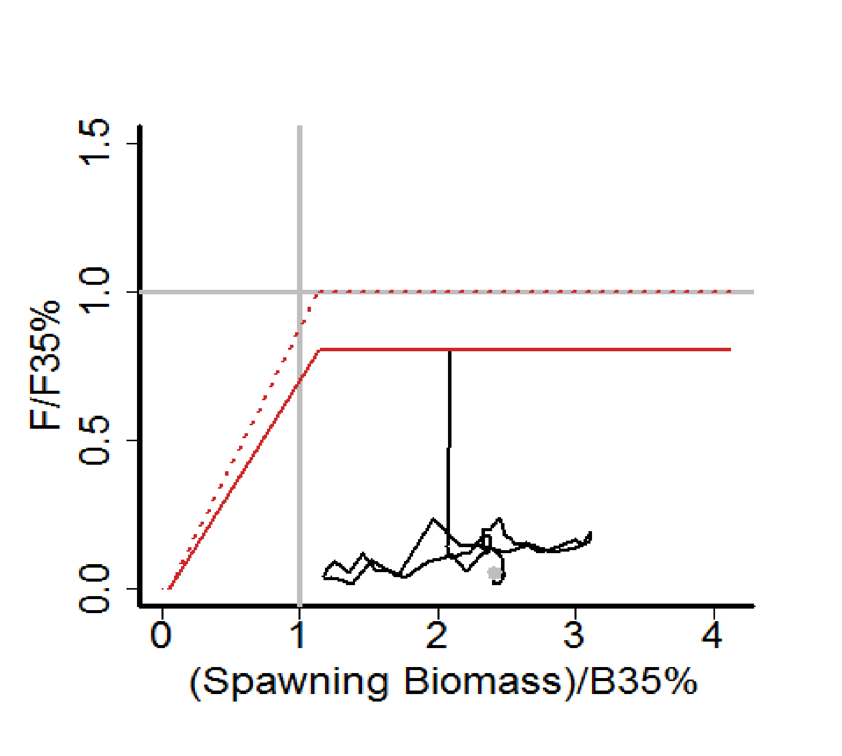
Model 18.2c: Retrospective plots





Executive summary

Projections:
- Catch for 2018 = 5yr average of tons caught between Oct 6 and Dec 31 added to catch-to date as of Oct 6
- Catch for 2019 and 2020 = 5 yr average catch (2013-2017)



Quantity	As estimated or *specified last* year for: 2018	2019	As estimated or *recommended this* year for: 2019*	2020*
M (natural mortality rate)	0.2	0.2	0.2	0.2
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	762,513	777,961	673,718	686,431
Projected Female spawning biomass (t)	214,124	205,156	153,203	155,032
$B_{100\%}$	322,938	322,938	212,060	212,060
$B_{40\%}$	129,175	129,175	84,824	84,824
$B_{35\%}$	113,028	113,028	74,221	74,221
F_{OFL}	0.41	0.41	0.47	0.47
$maxF_{ABC}$	0.34	0.34	0.38	0.38
F_{ABC}	0.34	0.34	0.38	0.38
OFL (t)	79,862	78,036	80,918	83,190
maxABC (t)	66,773	65,227	66,625	68,448
ABC (t)	66,773	65,227	66,625	68,448
Status	As determined *last* year for: 2016	2017	As determined *this* year for: 2017	2018
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Future research

- Exploration of spatial dynamics of flathead sole with respect to the cold pool (proposal underway)
- Investigation of methods for assessment species complexes (proposal written, not funded YET)
- Stock structure analysis and possible use of slope data
- Better accounting for uncertainty in catchability and natural mortality