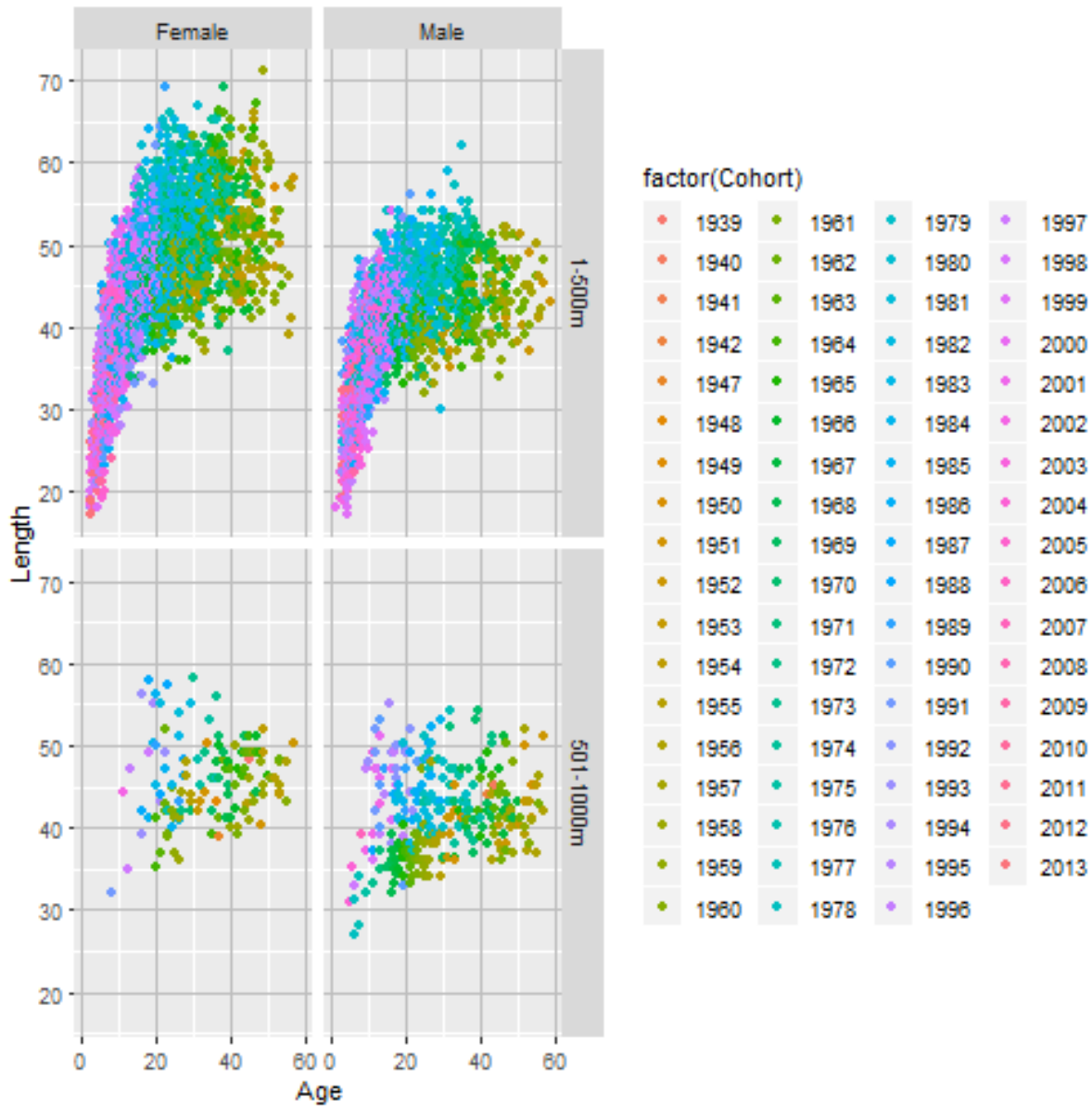
Movement Model


Female
Male
1-500m
501-1000m
Length
Age
0
20
40
60
20
30
40
50
60
70
factor(Cohort)
1939
1940
1941
1942
1947
1948
1949
1950
1951
1952
1953
1954
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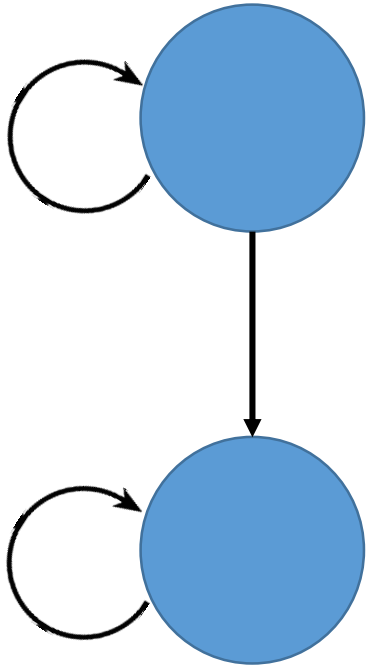
2007
2008
2009
2010
2011
2012
2013

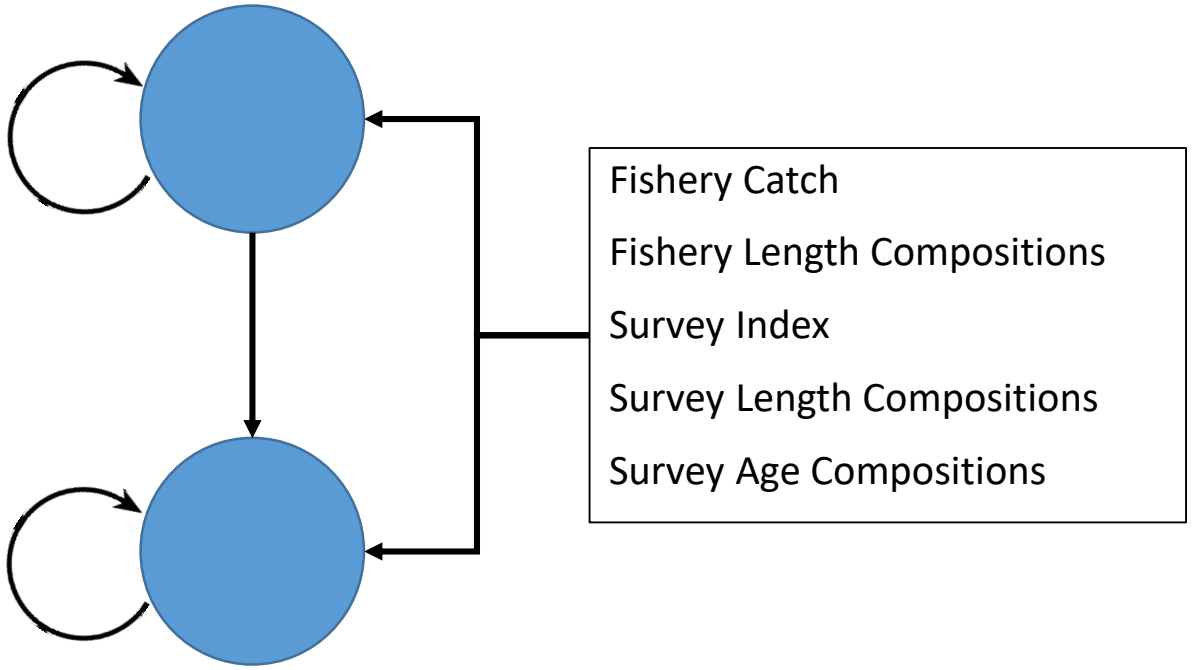
Two Area Box Model with Movement

- Shallow: 0-500m
- Deep: 501-1000m



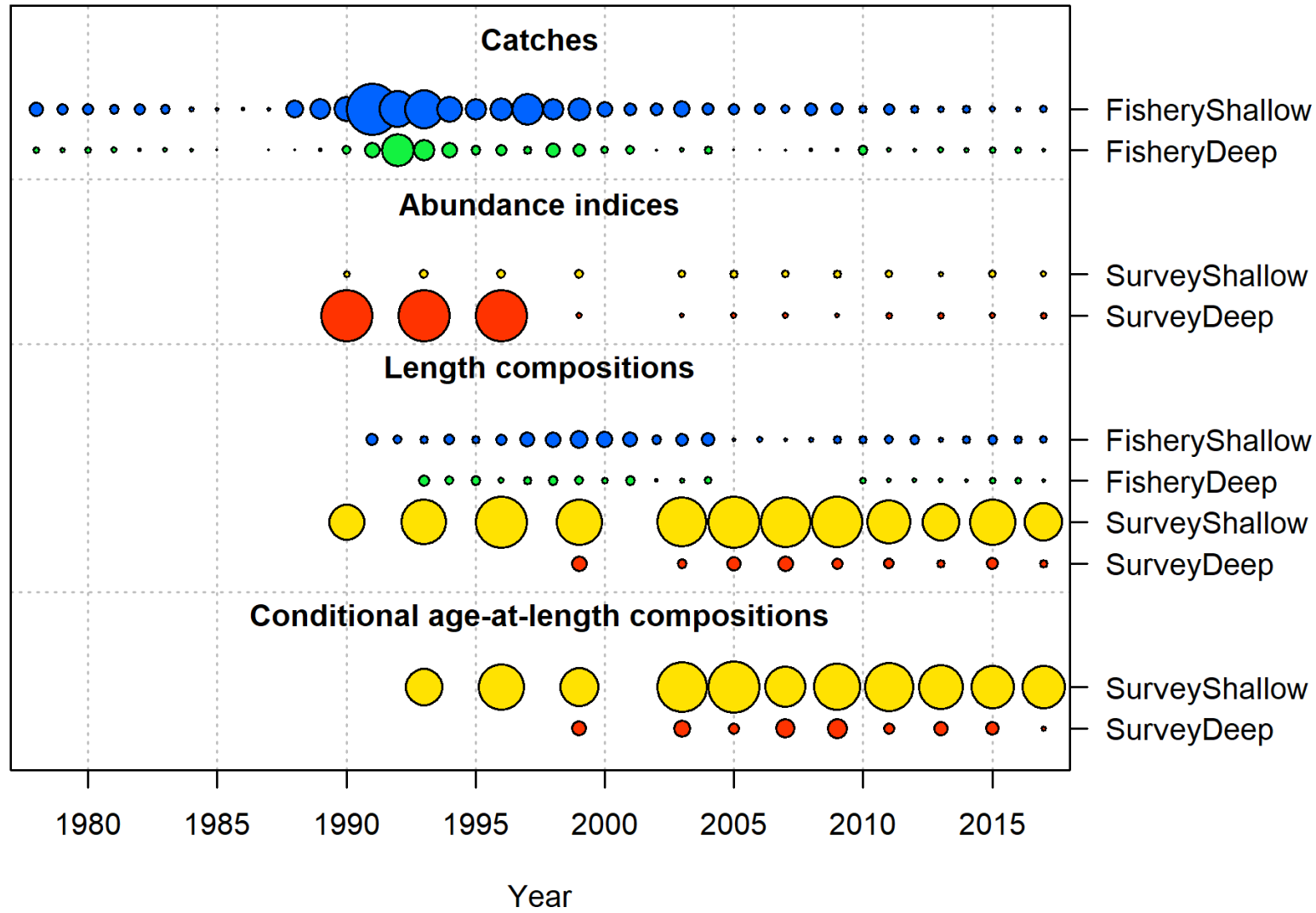
Two Area Box Model with Movement

- Shallow: 0-500m
- Deep: 501-1000m



Information for shallow selectivity

Year	Max Depth Surveyed
1984	1000m
1987	1000m
1990	500m
1993	500m
1996	500m
1999	1000m
2001	500m
2003	700m
2005	1000m
2007	1000m
2009	500m
2011	700m
2013	700m
2015	1000m
2017	700m

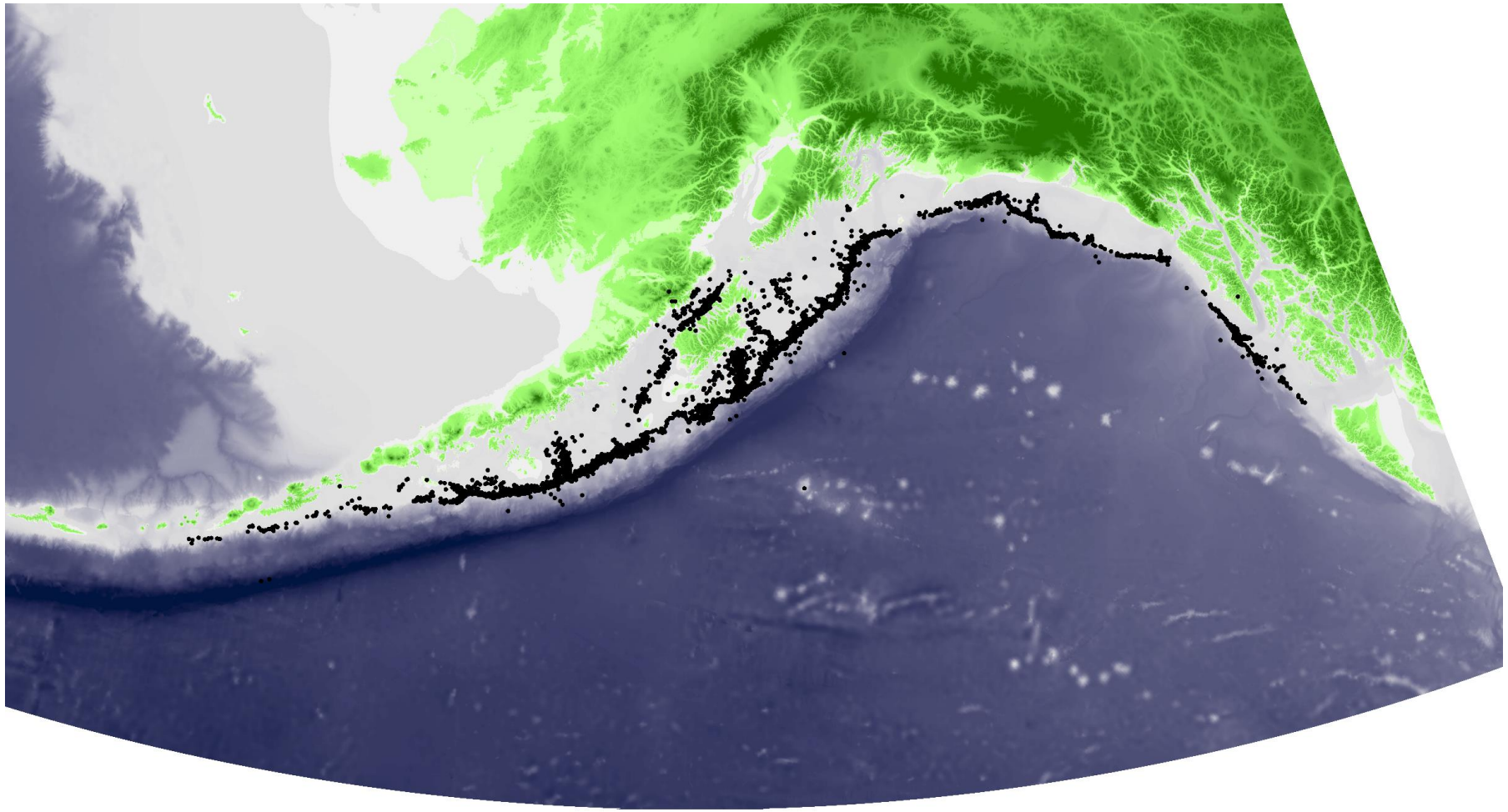

Catches
FisheryShallow
FisheryDeep
Abundance indices
SurveyShallow
SurveyDeep
Length compositions
FisheryShallow
FisheryDeep
SurveyShallow
SurveyDeep
Conditional age-at-length compositions
SurveyShallow
SurveyDeep
1980
1985
1990
1995
2000
2005
2010
2015
Year

Proportion Shallow/Deep

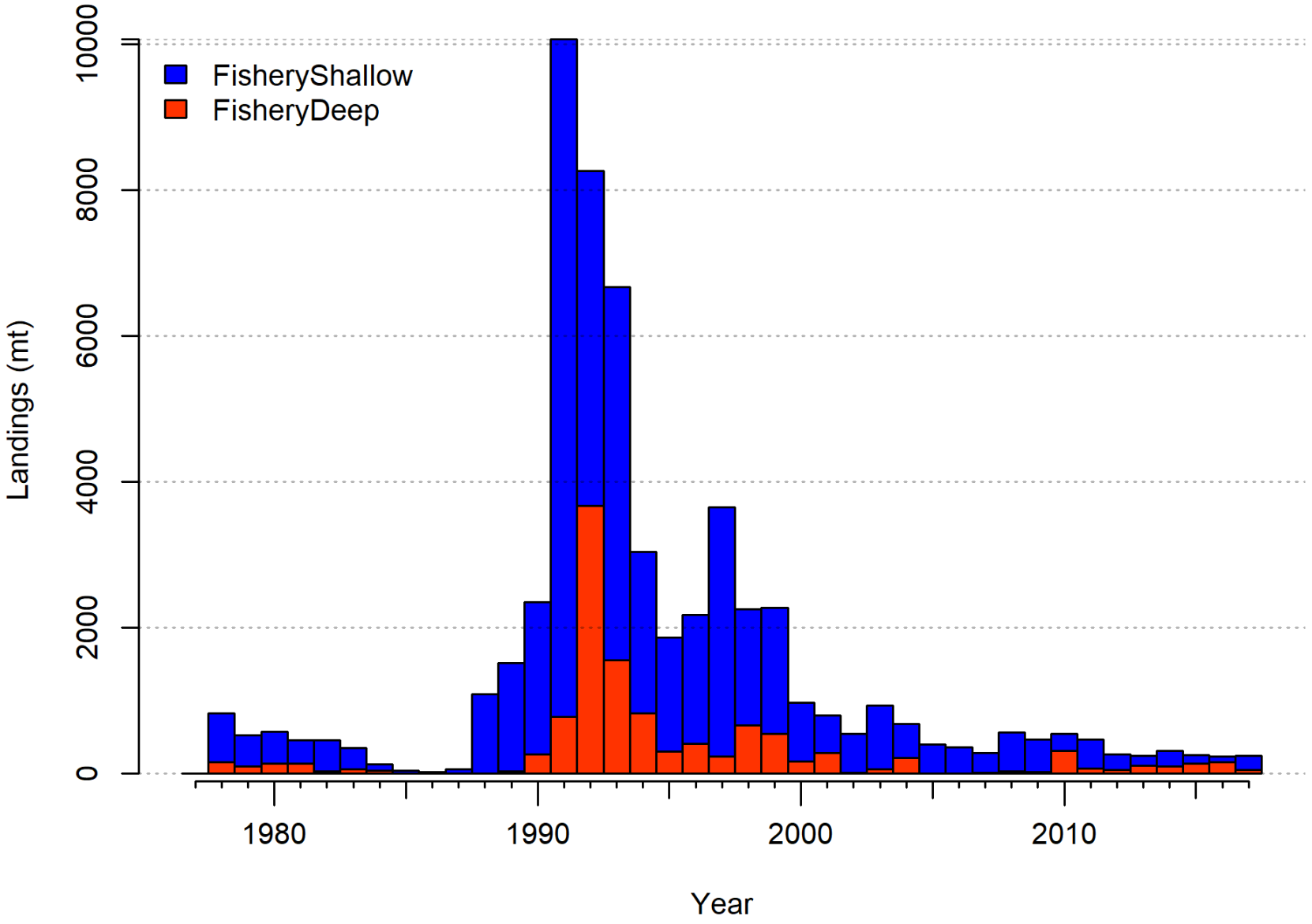
Fishery Data

- Catch Data
  - 1987-2017: Bottom depth from Observer Database
  - 1978-1986: Extracted depth values from GOA bathymetric grid using latitude and longitude data from NORPAC

Norpac Catch Data, 1978-1986



Catch Data


FisheryShallow
FisheryDeep
Landings (mt)
0
2000
4000
6000
8000
10000
1980
1990
2000
2010
Year

Proportion Shallow/Deep

Fishery Data

- Catch Data
  - 1987-2017: Bottom depth from Observer Database
  - 1978-1986: Extracted depth values from GOA bathymetric grid using latitude and longitude data from NORPAC

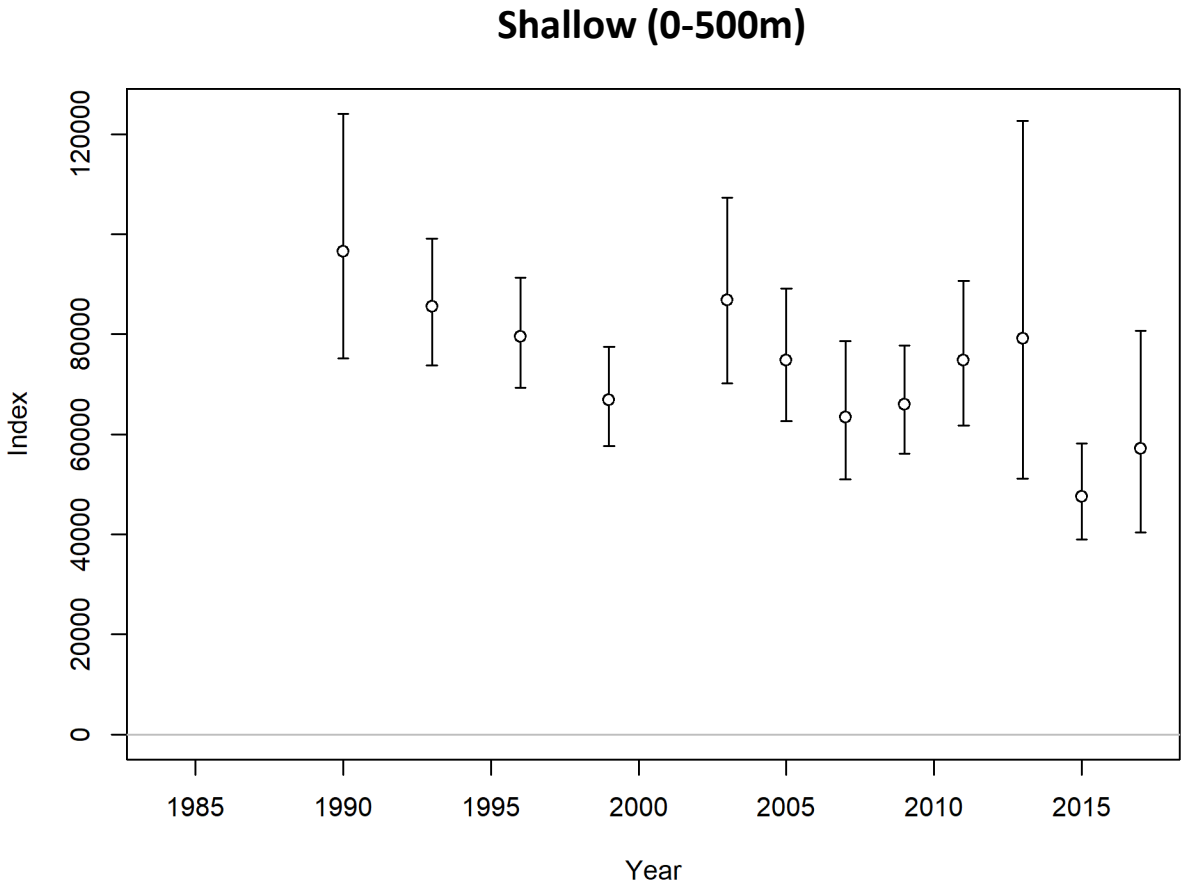
- Length Composition Data
  - 1991-2017: Bottom depth from Observer Database

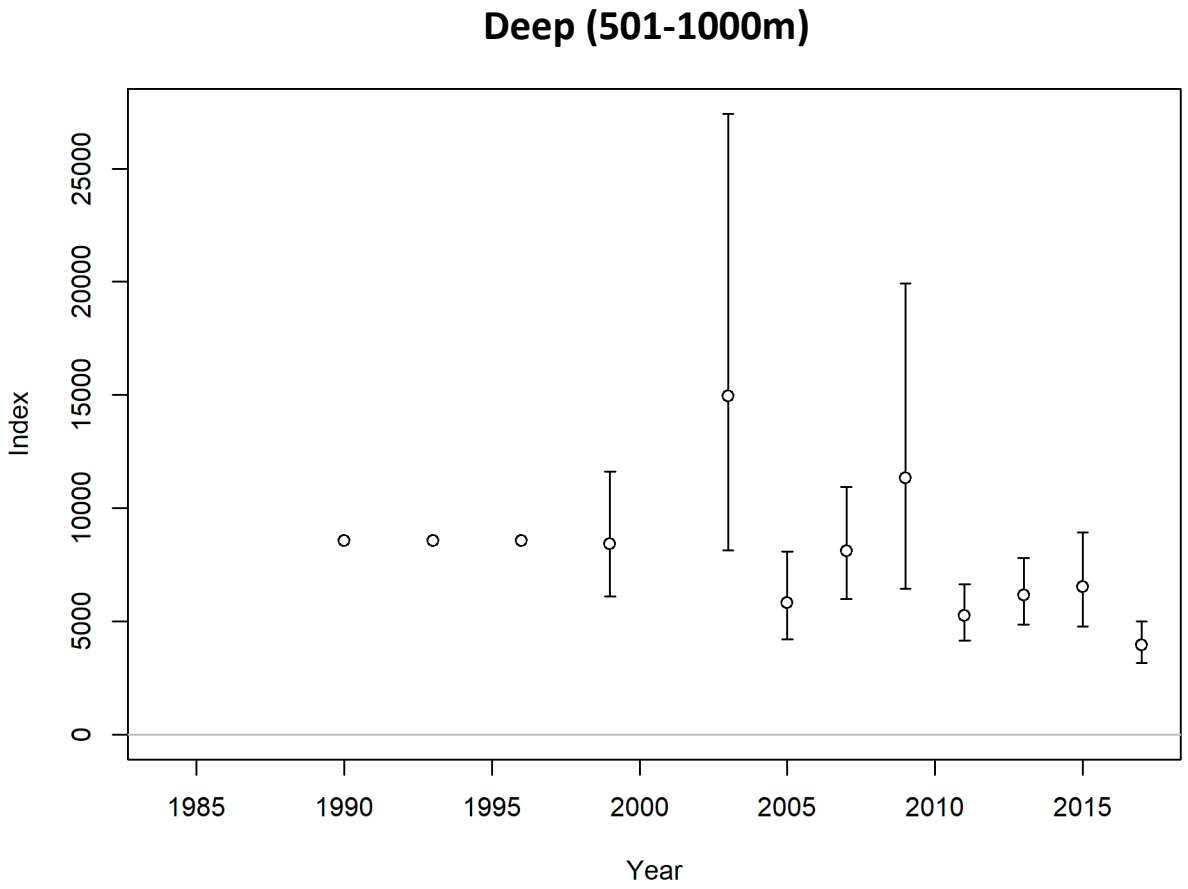
Proportion Shallow/Deep

Survey Data

- Biomass Index
  - 1984-Present: Bottom depth from RaceBase
  - Used random effects model to fill in depth-area gaps

Biomass Index



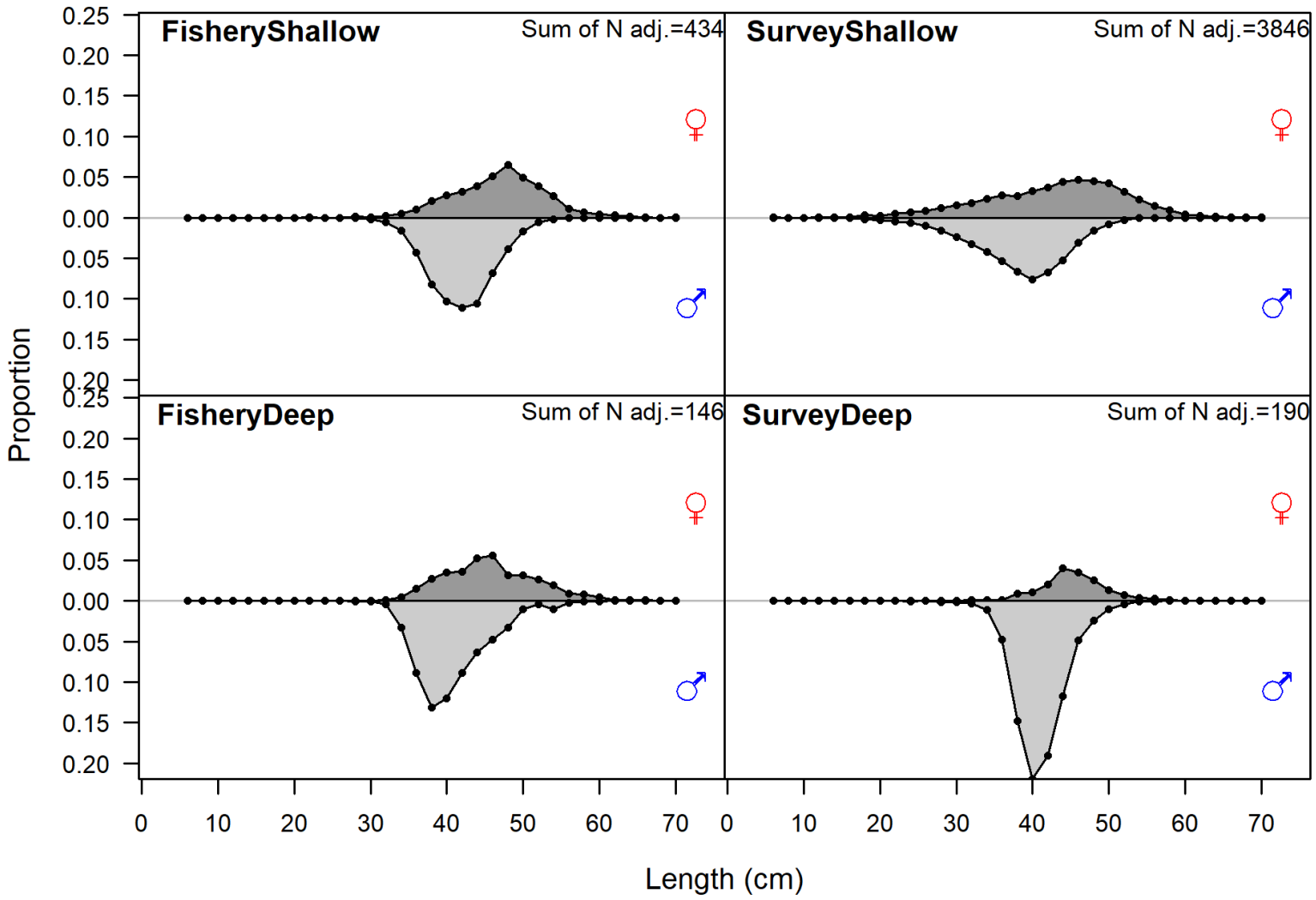


Proportion Shallow/Deep

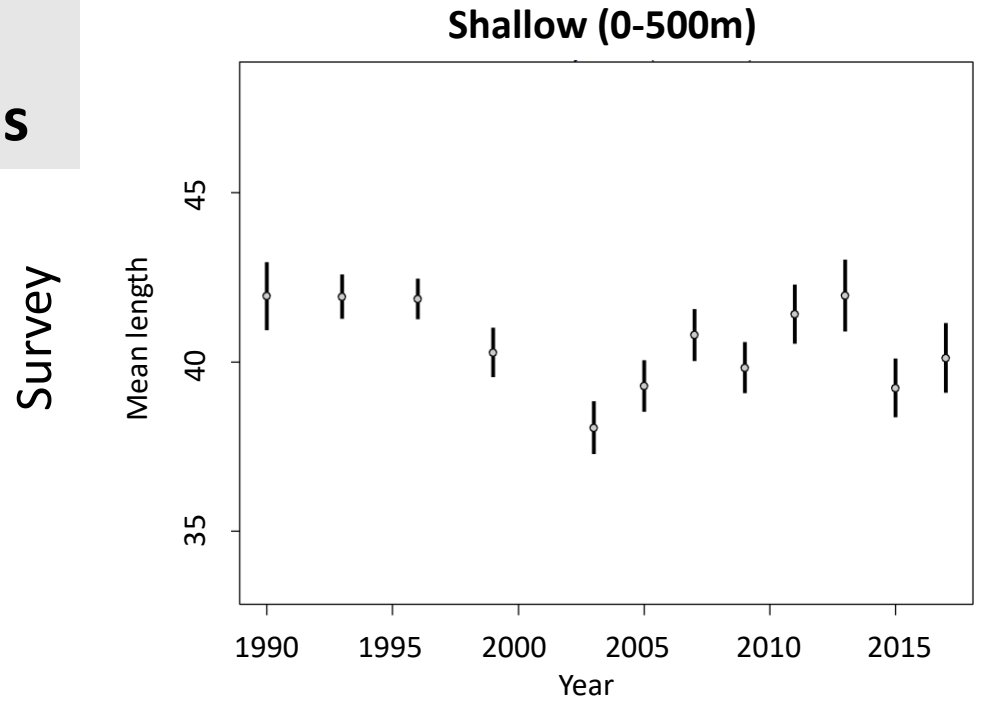
Survey Data

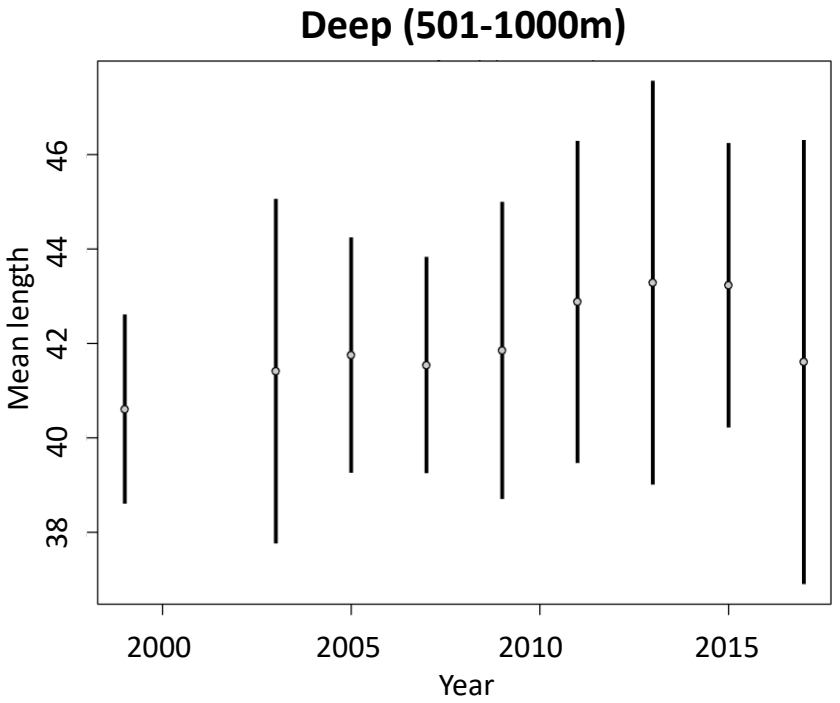
- Biomass Index
  - 1984-2017: Bottom depth from RaceBase
  - Used random effects model to fill in depth-area gaps
- Length Composition Data
  - 1984-2017: Summary depth from GOA Database
- Conditional Age at Length Data
  - 1984-2017: Max depth from GOA Database

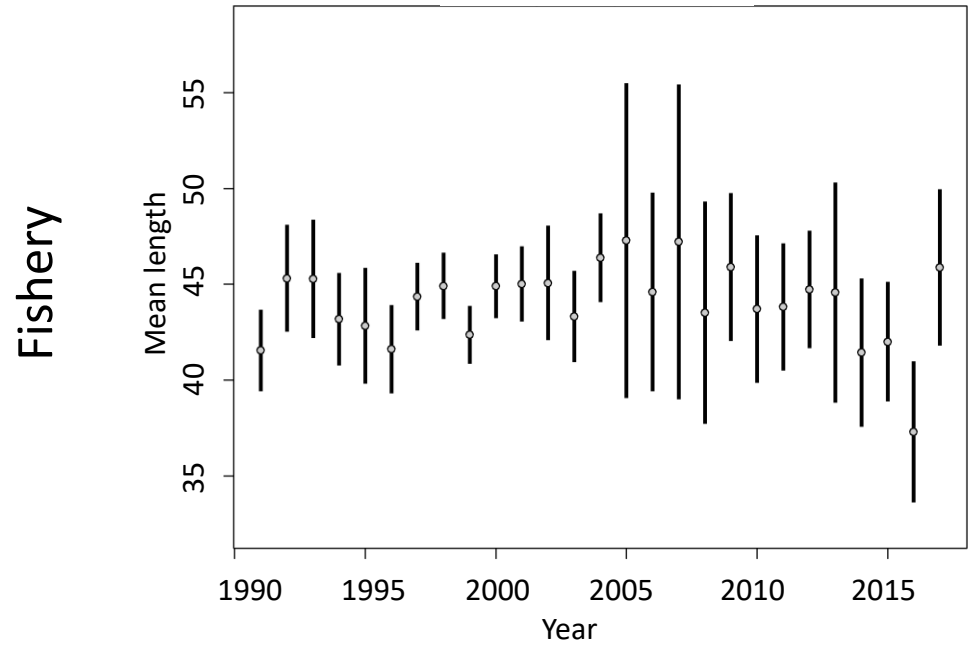
Length Compositions

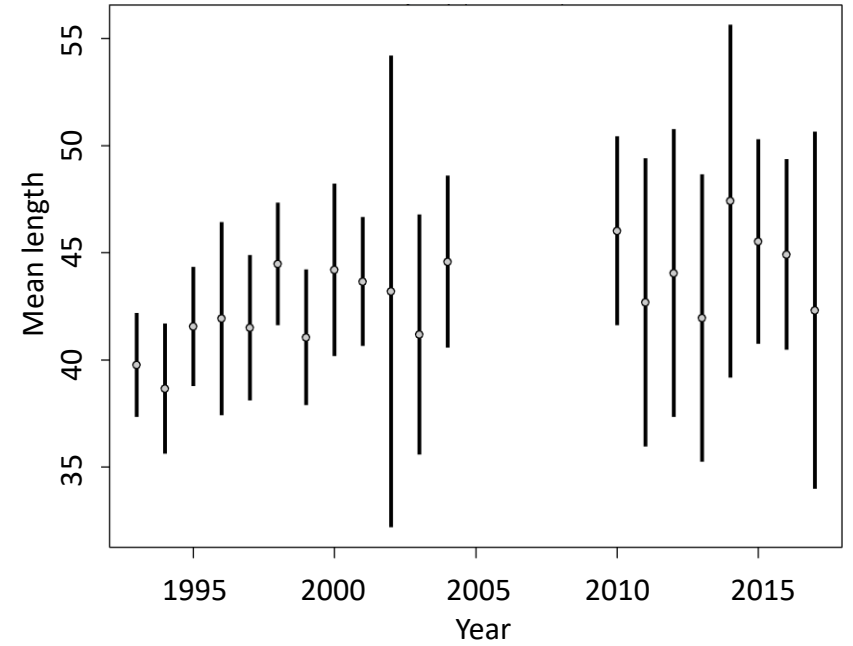


Mean Lengths

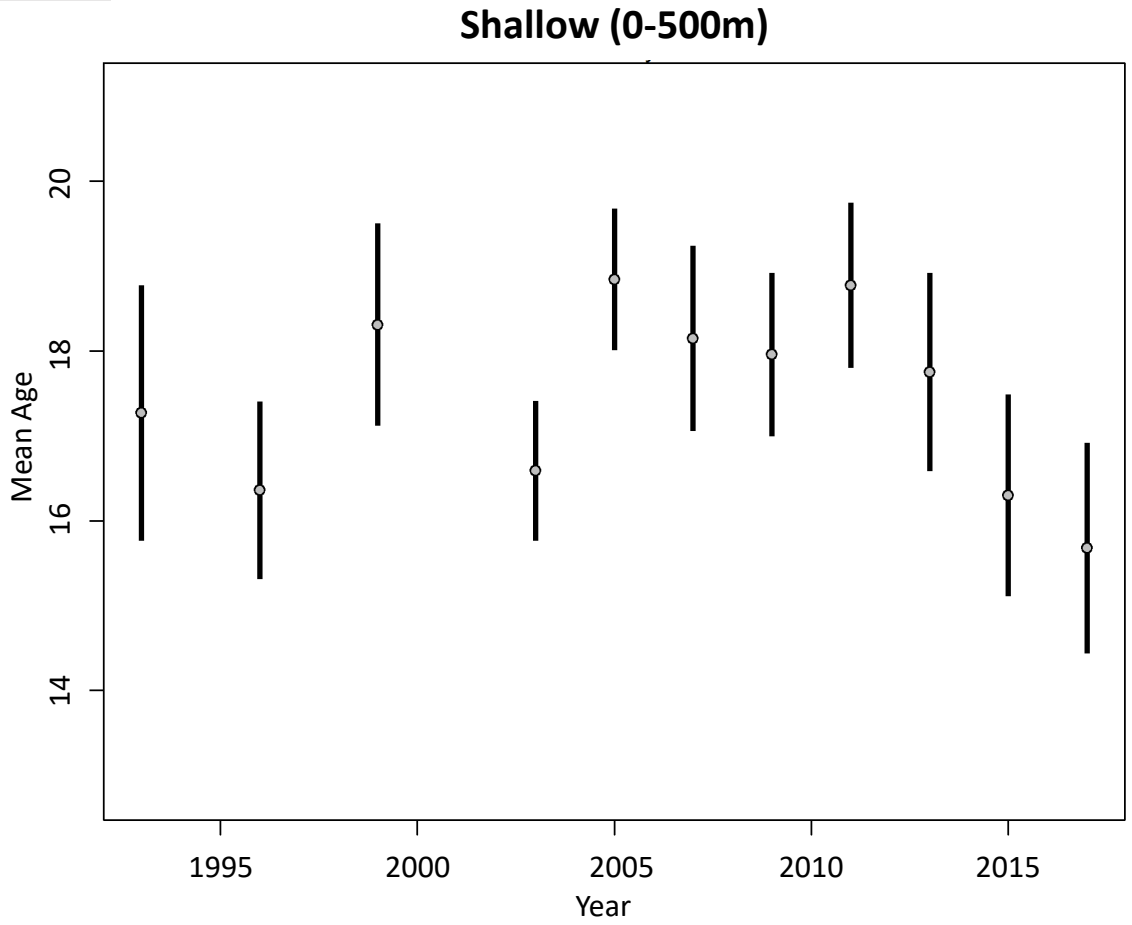


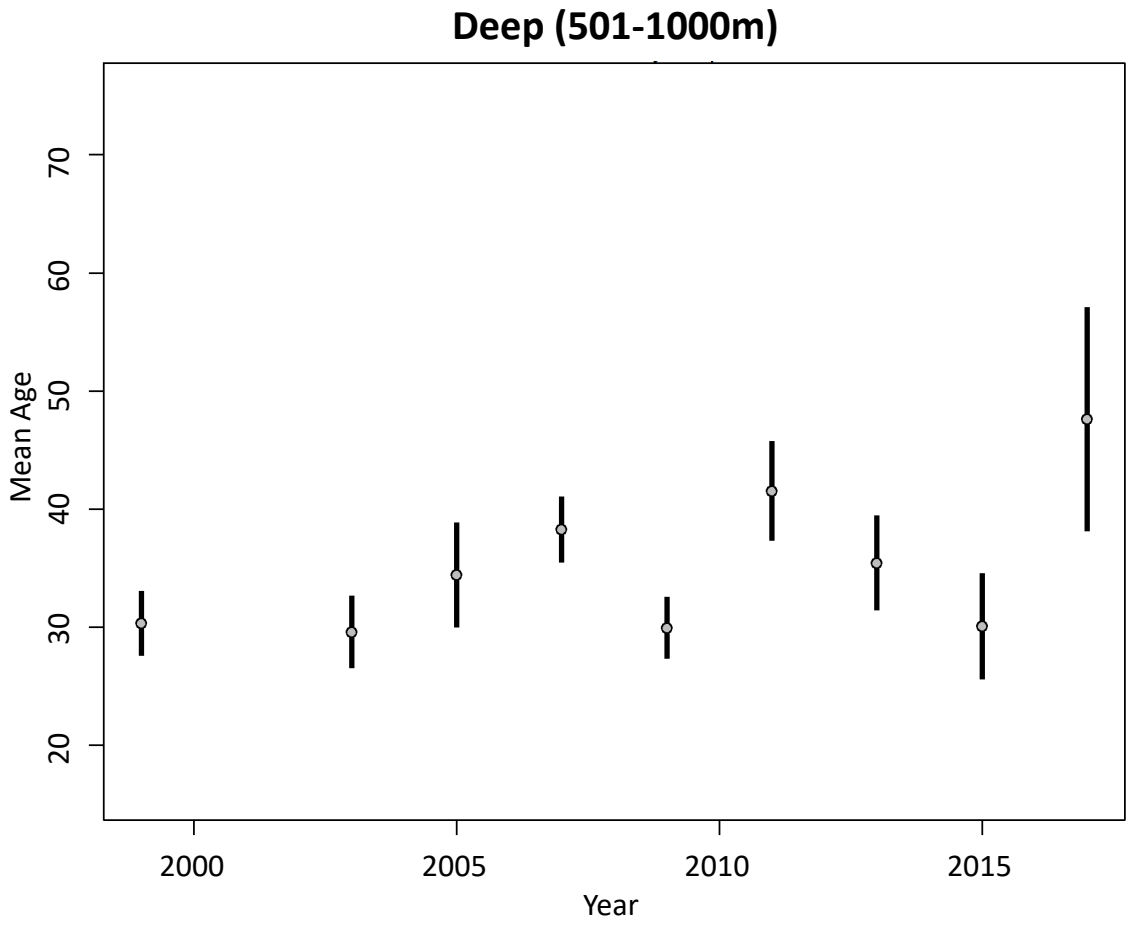






Mean Survey Ages





Data and Model Limitations

- Estimate growth outside the model
  - Data Needs: Split marginal age data by depth strata
- Sex-Specific Movement
  - Model Needs: Updates to SS to allow for movement by sex
- GOA specific ageing error
- More data exploration
- Fewer age/length bins

Simple Movement Model Structure (Model 0)

- Two Areas (Shallow: 0-500 and Deep: 501-1000)
- Two Growth Patterns for each sex
  - Female Shallow
  - Female Male
  - Male Shallow
  - Male Deep
- Two movement definitions were specified:
  - Movement from shallow to deep for ages 3 to 10
  - Movement from deep to shallow for ages 3 to 10

Parameters estimated outside the model

- Natural mortality (0.085, as for previous assessments)
- Shallow and deep catchability (1, as for previous assessments)
- Weight-length relationship
- Maturity-at-age
- SigmaR = 0.49

Parameters estimated outside the model

- Recruitment Distribution (probability of shallow recruitment is fixed to 1)
- Shallow and deep sex-specific parameters of the von-Bertalanffy growth curve
- CV of length-at-age for ages 2 and 59
- Movement Parameters:
  - Movement from deep to shallow fixed at 0
  - Probability of movement at youngest age fixed to 0
- Logistic Selectivity – Mirrored between shallow and deep

Parameters estimated inside the model

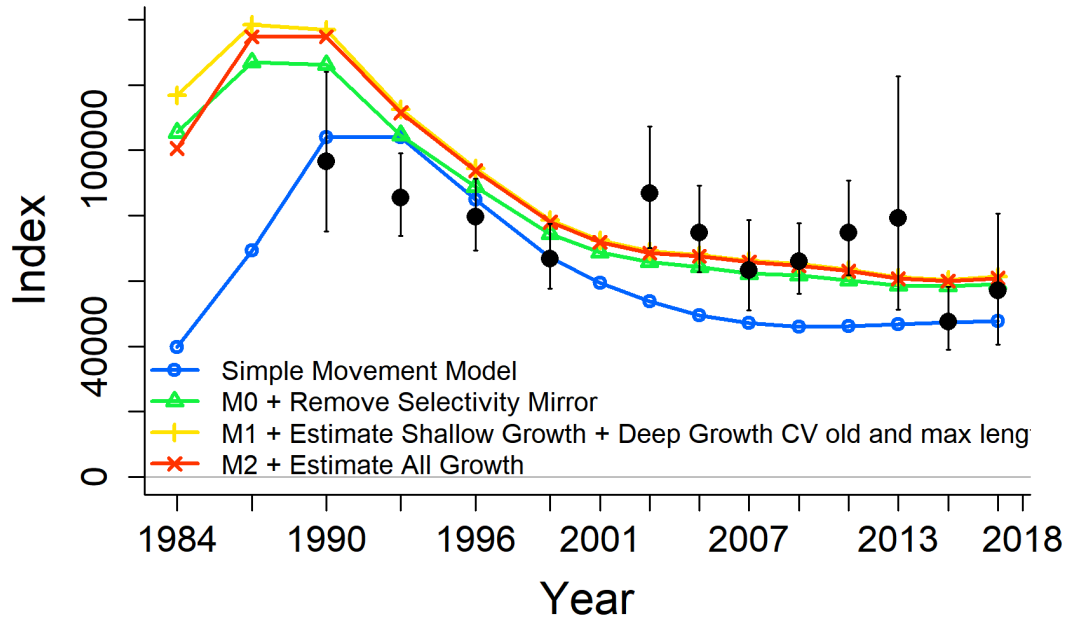
- ln(R0)
- log-scale recruitment deviations
- yearly fishing mortality
- Selectivity parameters for the fishery shallow and survey shallow – selectivities for deep mirrored from shallow

Model Trials

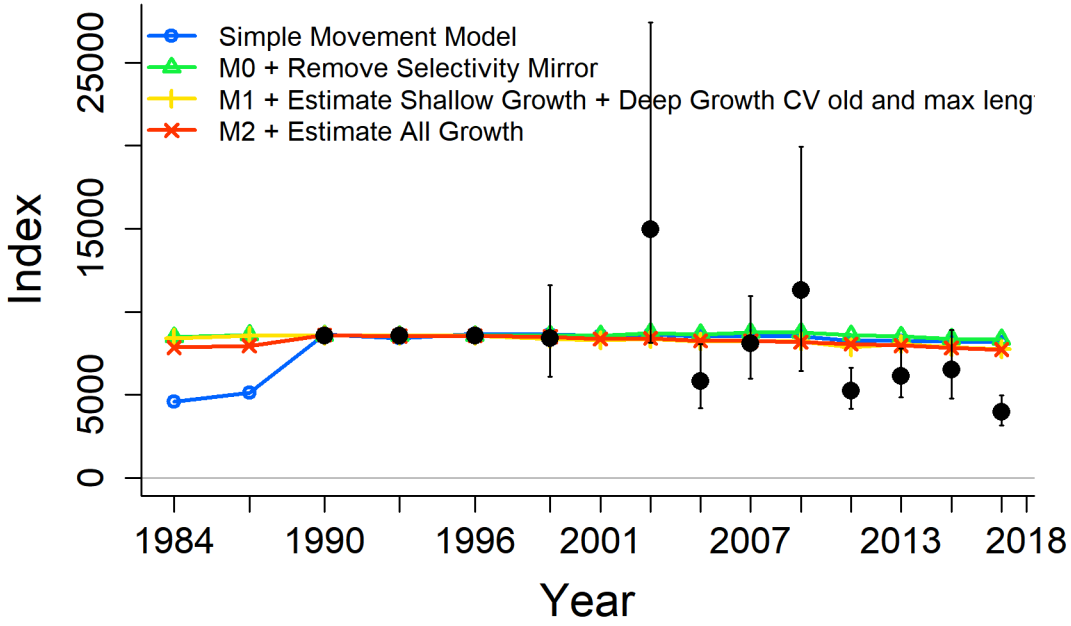
- Model 0: Simple Movement Model
- Model 1: Model 0 + Estimate deep and shallow selectivity separately (remove mirror)
- Model 2: Model 1 + Estimate von-Bertalanffy shallow growth and CVs and the following deep growth parameters: length at maximum and CV of age 59
- Model 3: Model 2 + Estimate all growth parameters

Fits to survey biomass data

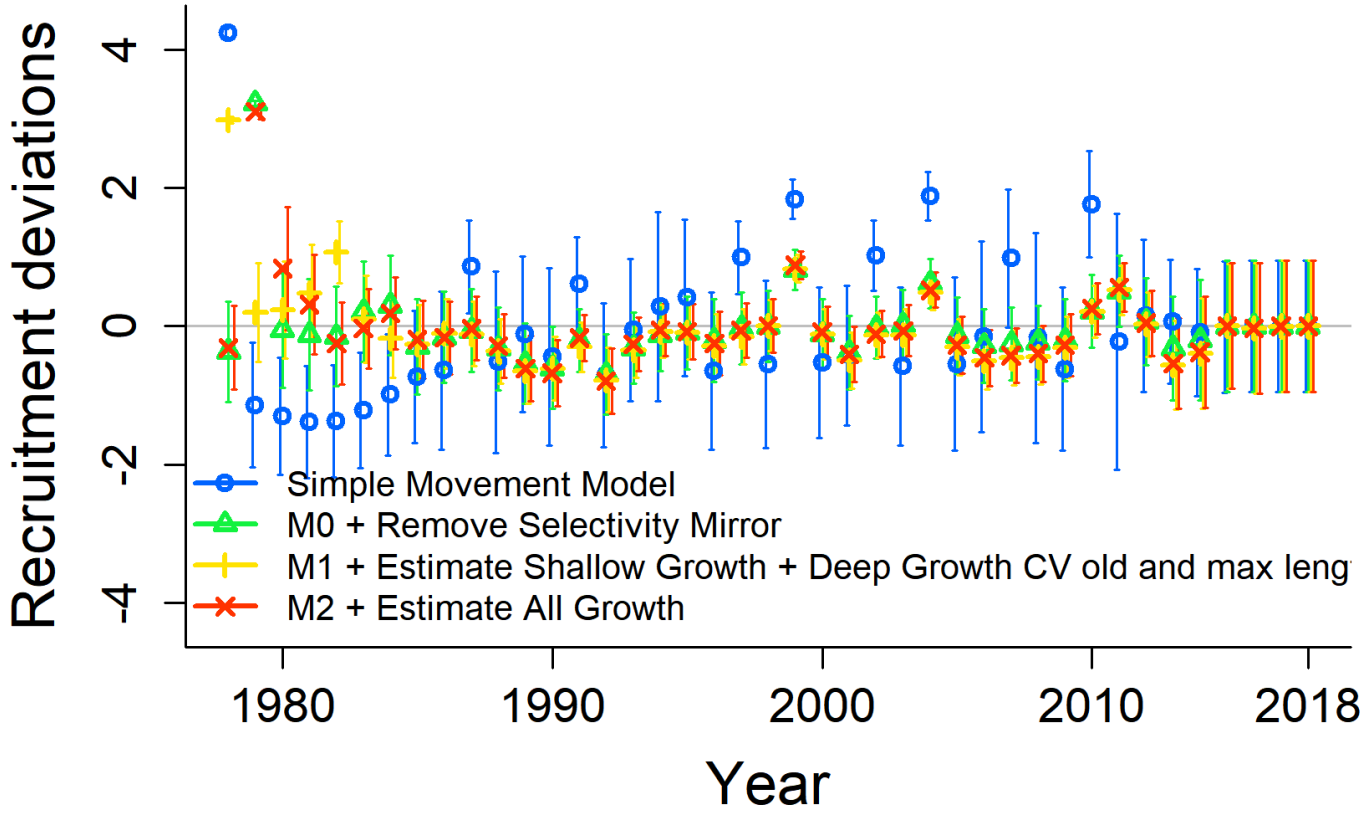
Shallow



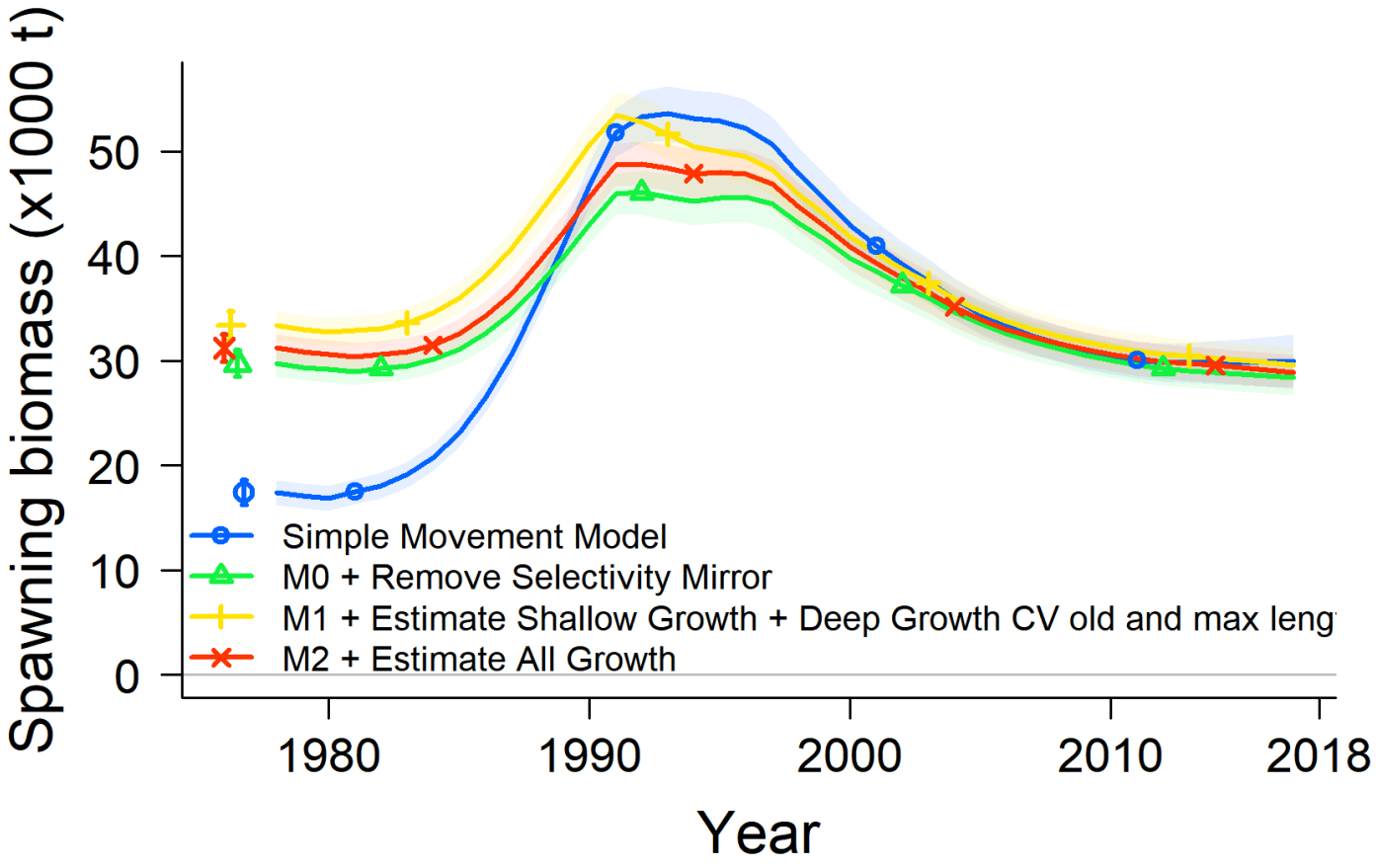
Deep



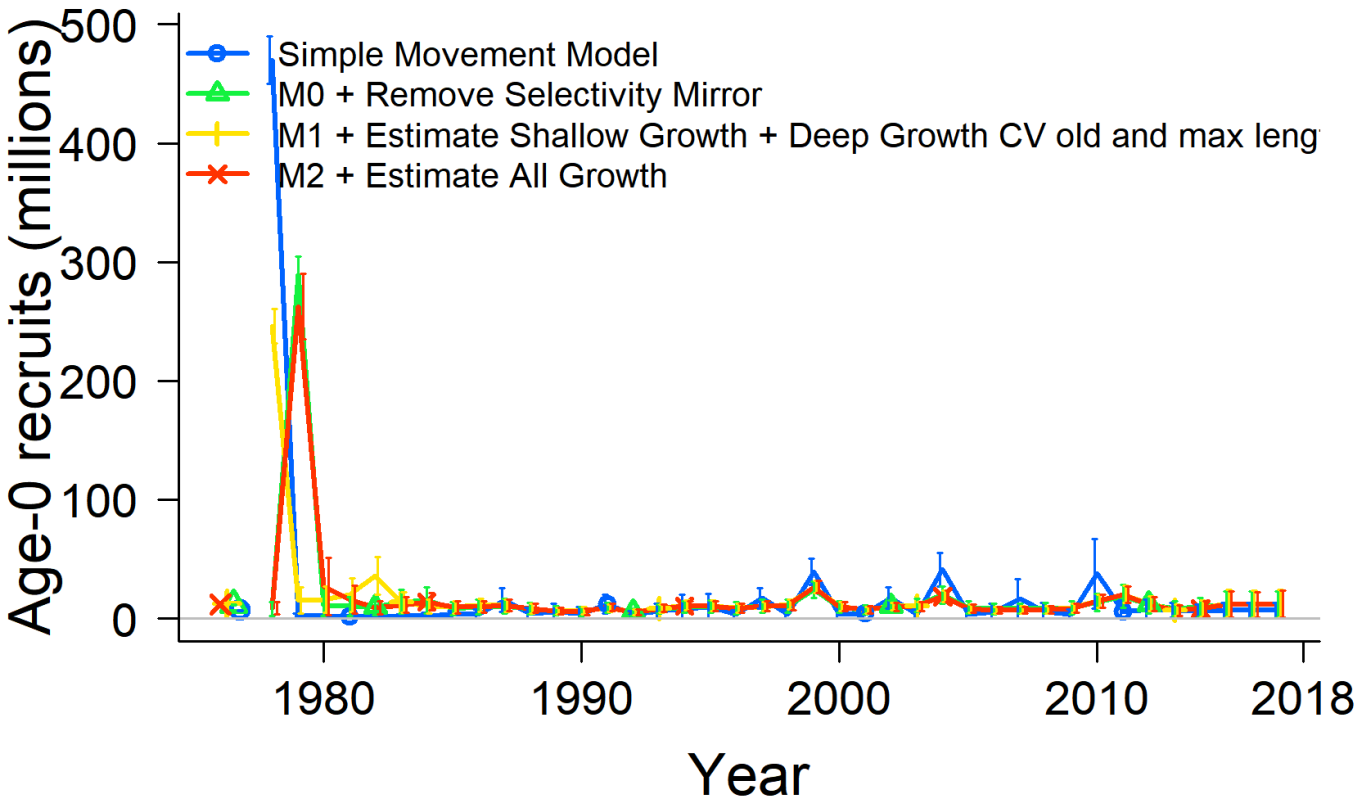
Recruitment Deviations



Spawning stock biomass

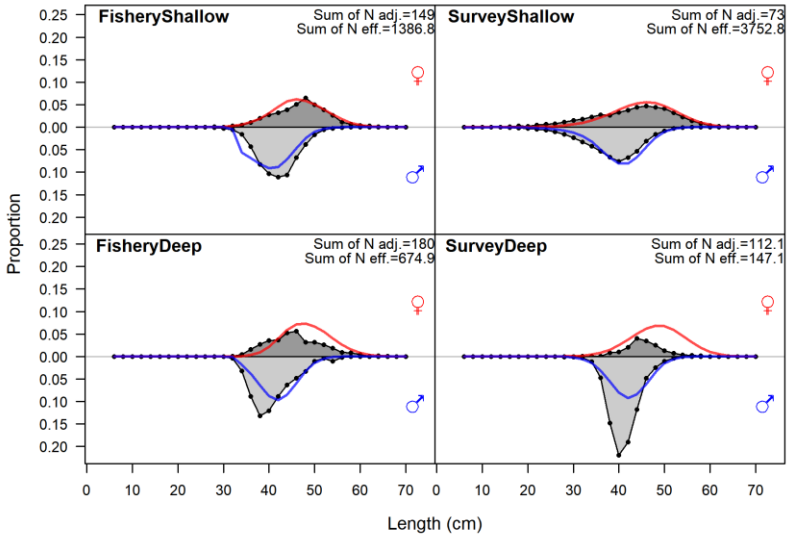


Recruitment

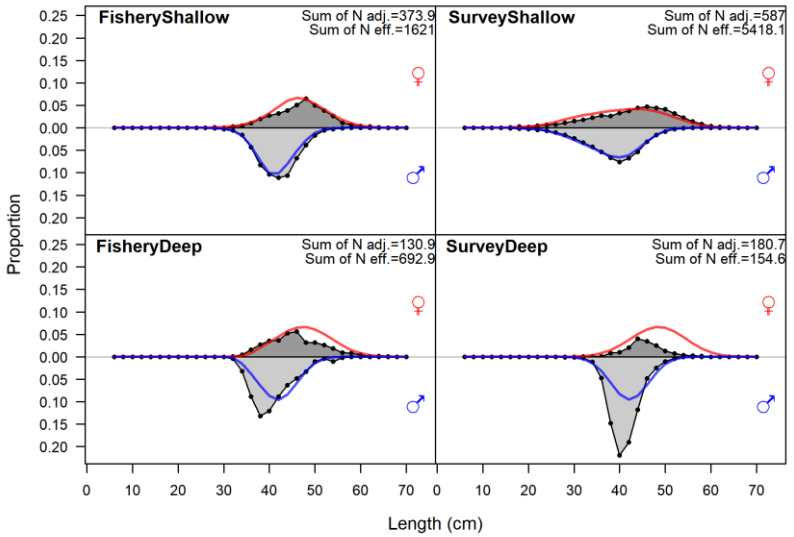


Aggregated Length Compositions

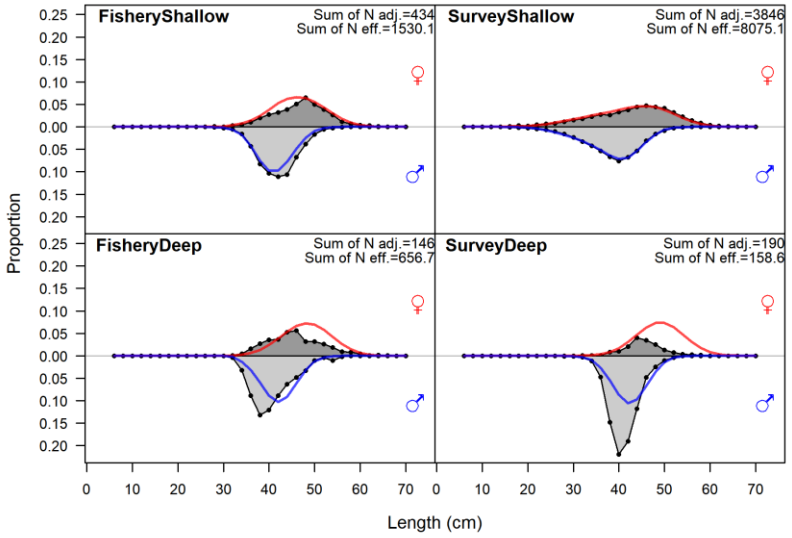
M0: Simple



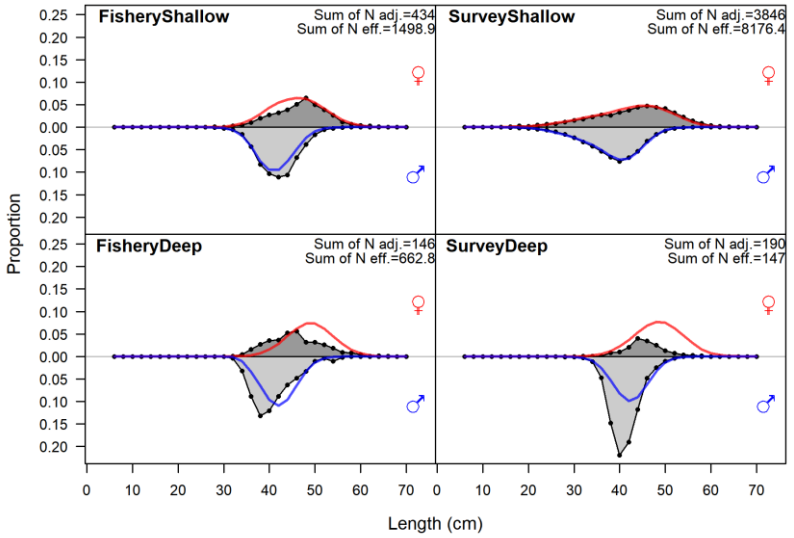
M1: M0 + Remove Selectivity Mirror



M2: M1 + Estimate Shallow Growth + Deep Growth age 59 CV and Length max

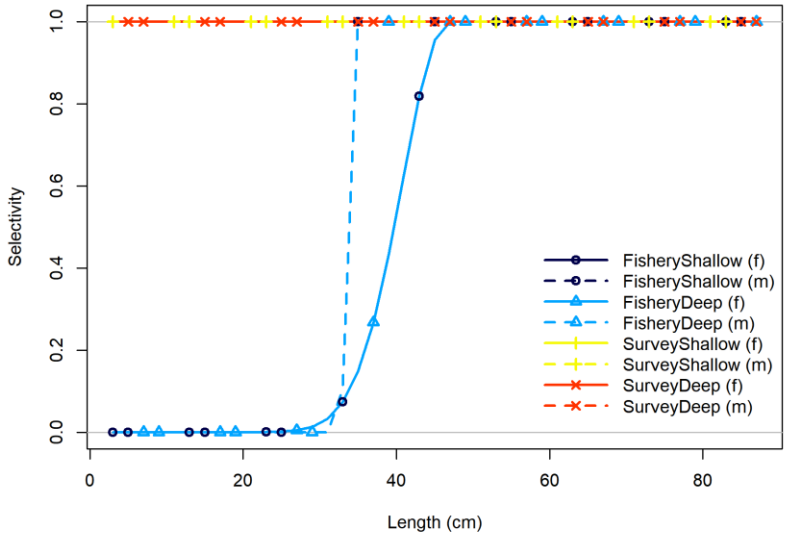


M3: M2 + Estimate All Growth

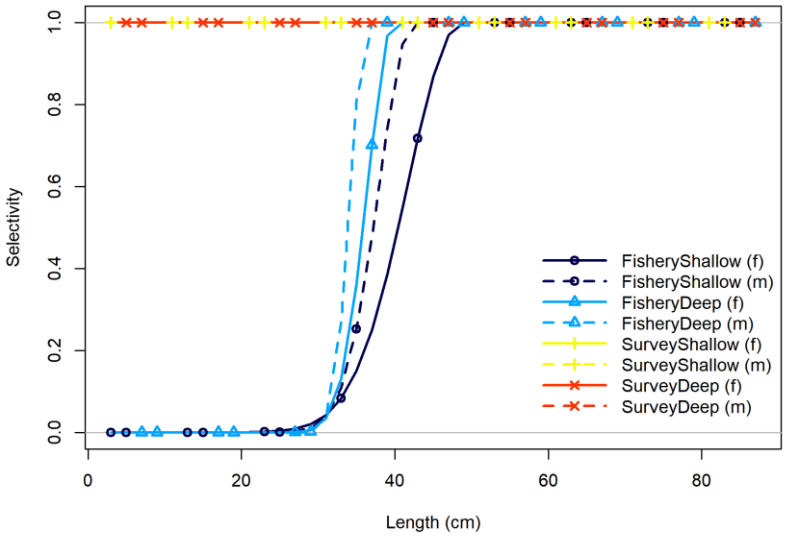


Fishery Length Selectivity

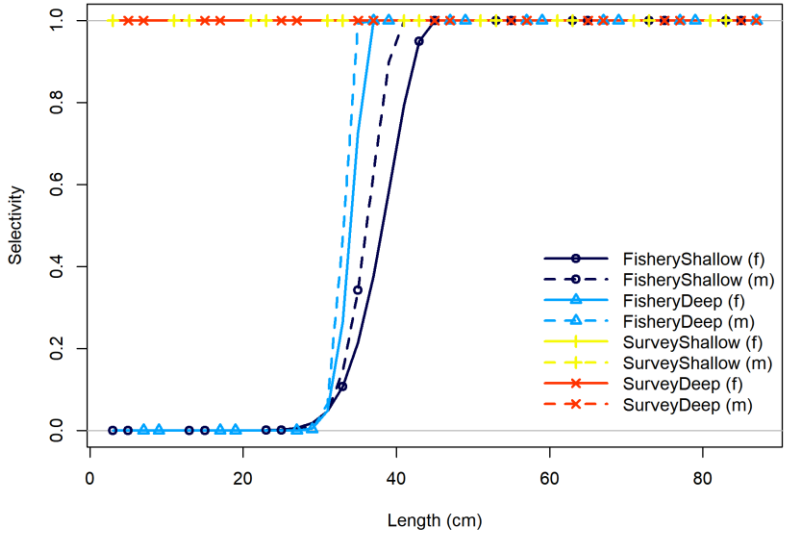
M0: Simple



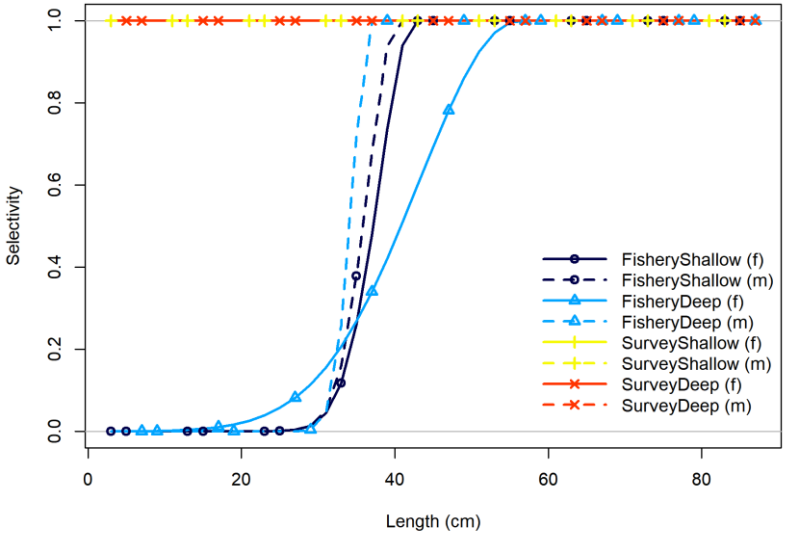
M1: M0 + Remove Selectivity Mirror



M2: M1 + Estimate Shallow Growth + Deep Growth age 59 CV and Length max

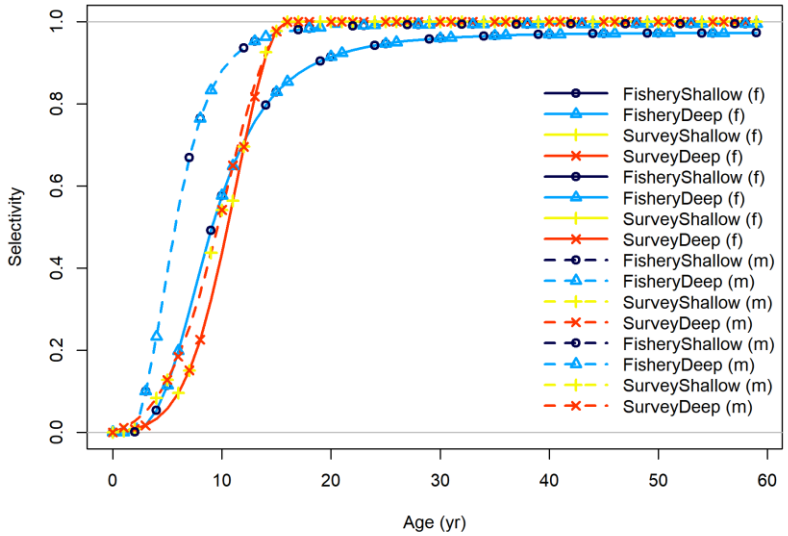


M3: M2 + Estimate All Growth

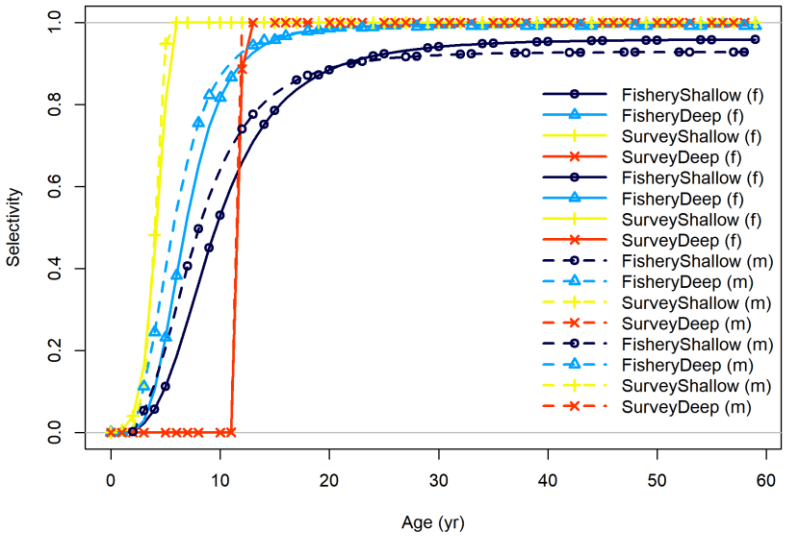


Age Selectivity

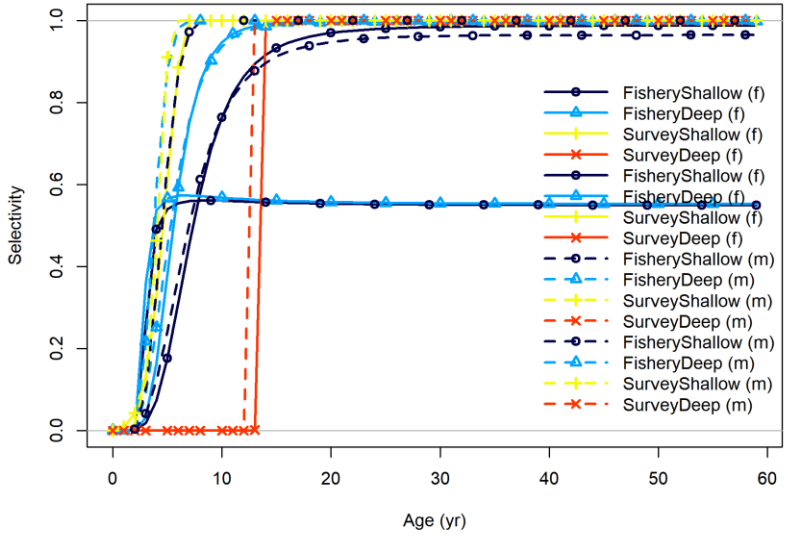
M0: Simple



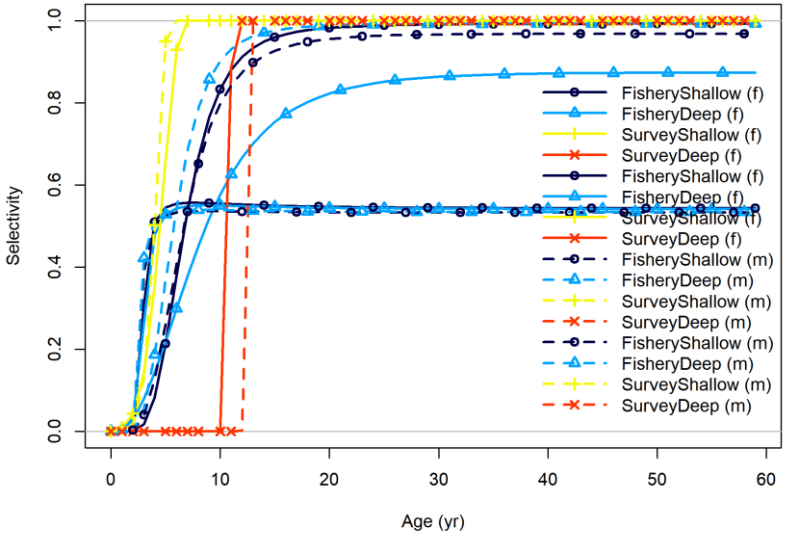
M1: M0 + Remove Selectivity Mirror



M2: M1 + Estimate Shallow Growth + Deep Growth age 59 CV and Length max



M3: M2 + Estimate All Growth

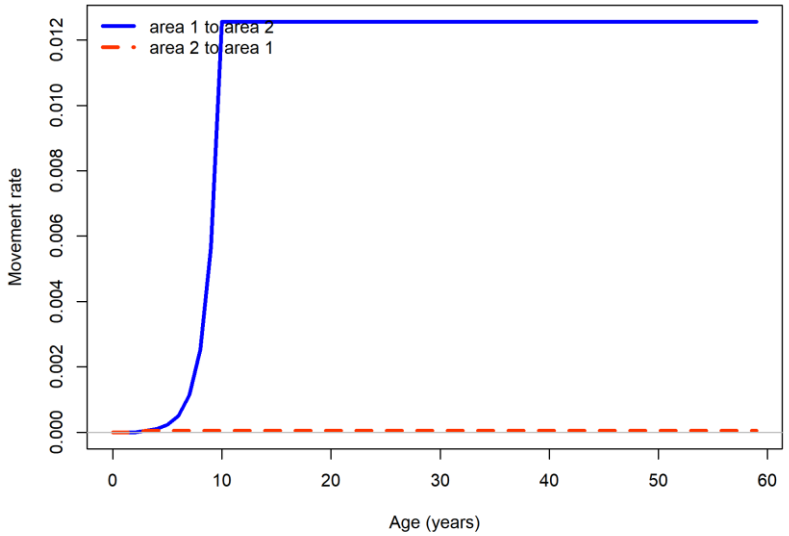


Movement Probabilities

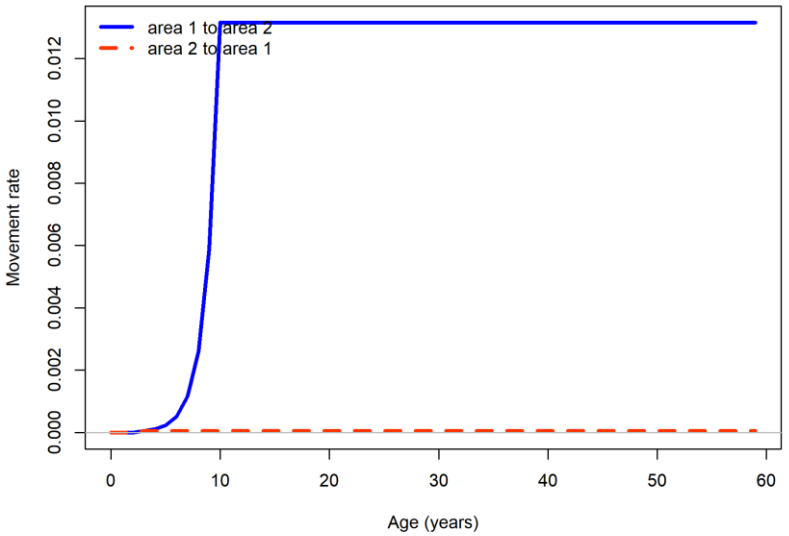
Movement Parameters	M0	M1	M2	M3
Probability of movement from Shallow to Deep at Age 5	0	0	0	0
Probability of movement from Shallow to Deep at Age 10	0.013	0.013	0.012	0.012
Probability of movement from Deep to Shallow at Age 5	0	0	0	0
Probability of movement from Deep to Shallow at Age 10	0	0	0	0

Movement Probability from Shallow to Deep

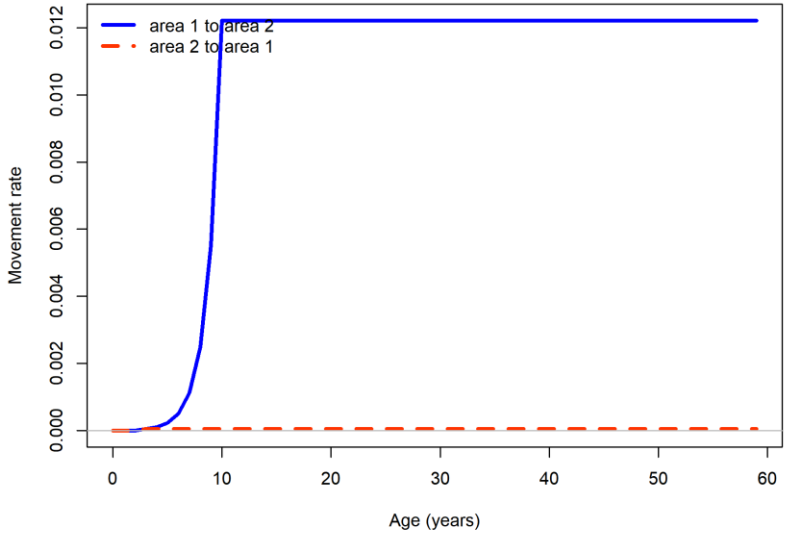
M0: Simple



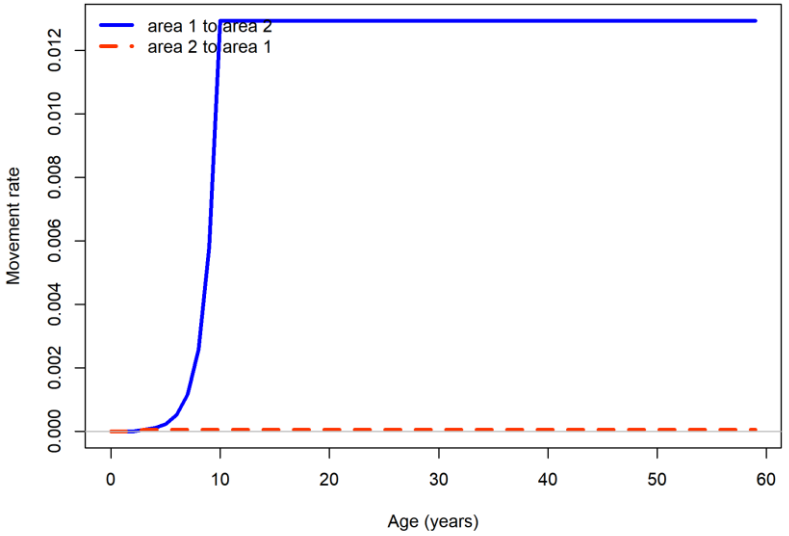
M1: M0 + Remove Selectivity Mirror



M2: M1 + Estimate Shallow Growth + Deep Growth age 59 CV and Length max



M3: M2 + Estimate All Growth



M2

Parameter	Value	Min	Max	Initial Value	Status	StdDev	Gradient
L_at_Amin_Fem_GP_1	24.1961	1	45	26.858	OK	0.424208	-0.00085001
L_at_Amax_Fem_GP_1	51.3607	10	100	52.1702	OK	0.228433	-0.0155426
VonBert_K_Fem_GP_1	0.146097	0.01	2	0.110543	OK	0.004885	-0.00667535
CV_young_Fem_GP_1	0.149825	0.0001	3	0.149679	OK	0.006466	-0.00039195
CV_old_Fem_GP_1	0.098753	0.0001	3	0.106165	OK	0.002355	-0.00241712
L_at_Amax_Fem_GP_2	100	10	100	52.101	HI	0.224184	-3.44E-06
CV_old_Fem_GP_2	4.99995	0.0001	5	0.107	HI	0.122316	1.67E-06
L_at_Amin_Mal_GP_1	25.527	1	45	28.4907	OK	0.48303	-0.00045005
L_at_Amax_Mal_GP_1	43.8458	20	70	44.0238	OK	0.153748	-0.00666804
VonBert_K_Mal_GP_1	0.187592	0.05	0.35	0.151851	OK	0.00843	-0.00057703
CV_young_Mal_GP_1	0.157138	0.0001	3	0.152772	OK	0.006207	-0.00019117
CV_old_Mal_GP_1	0.083868	0.0001	3	0.08912	OK	0.001955	-0.0015196
L_at_Amax_Mal_GP_2	59.5102	20	70	43.968	OK	3.17763	1.21E-06
CV_old_Mal_GP_2	0.0001	0.0001	5	0.09	LO	8.03E-05	-4.37E-06

M3

Parameter	Value	Min	Max	Initial Value	Status	StdDev	Gradient
L_at_Amin_Fem_GP_1	24.0075	1	45	26.858	OK	0.43116	-1.24E-06
L_at_Amax_Fem_GP_1	50.8314	10	100	52.1702	OK	0.221294	-7.78E-05
VonBert_K_Fem_GP_1	0.15344	0.01	2	0.110543	OK	0.005128	-2.14E-05
CV_young_Fem_GP_1	0.14909	0.0001	3	0.149679	OK	0.006718	-3.72E-06
CV_old_Fem_GP_1	0.102725	0.0001	3	0.106165	OK	0.002484	-3.47E-05
NatM_p_1_Fem_GP_2	0.01	0.01	1	0.085	LO	2.8E-06	-2.85E-07
L_at_Amin_Fem_GP_2	47.5777	1	50	25.366	OK	6.94613	1.18E-05
L_at_Amax_Fem_GP_2	11.4603	10	100	52.101	OK	3.42014	-3.44E-07
VonBert_K_Fem_GP_2	1.99967	0.01	2	0.113	HI	0.470251	1.01E-06
CV_young_Fem_GP_2	0.000112	0.0001	6	0.15	LO	0.029557	3.37E-06
CV_old_Fem_GP_2	6	0.0001	6	0.107	HI	0.008736	-8.39E-11
L_at_Amin_Mal_GP_1	25.2455	1	50	28.4907	OK	0.493941	-1.74E-07
L_at_Amax_Mal_GP_1	43.6737	20	70	44.0238	OK	0.150179	-8.60E-06
VonBert_K_Mal_GP_1	0.196616	0.05	0.35	0.151851	OK	0.008749	-6.86E-08
CV_young_Mal_GP_1	0.158327	0.0001	3	0.152772	OK	0.006433	-3.52E-07
CV_old_Mal_GP_1	0.0848	0.0001	3	0.08912	OK	0.001944	-4.36E-06
L_at_Amin_Mal_GP_2	10.8604	1	50	27.11	OK	67.3837	-1.25E-06
L_at_Amax_Mal_GP_2	57.6068	20	70	43.968	OK	309.773	-2.67E-08
VonBert_K_Mal_GP_2	0.399441	0.05	0.4	0.158	HI	0.332814	3.77E-06
CV_young_Mal_GP_2	5.99979	0.0001	6	0.151	HI	0.513821	6.55E-08
CV_old_Mal_GP_2	5.99996	0.0001	6	0.09	HI	0.101522	-2.35E-08

Future Directions

- Estimate growth outside the model
- Estimate sex-specific movement
- GOA specific ageing error
- Explore fishery selectivity

Conditional age-at-length standard deviation plots

$$\text{Std Dev} = \sqrt{\text{age}^2(\text{proportion-at-age})\text{-}(\text{age} \times \text{proportion-at-age})^2}$$

- Observed standard deviations are often low (or 0) for larger length bins because there are few samples (or 1 sample) in those bins
- Expected standard deviations at larger length bins are a direct function of the modeled numbers at age and length.
  - standard deviations reflect the model's interpretation of the population variability in ages within a length bin and not a standard deviation calculated from a sample.
- Variability in expected standard deviation can occur from year to year due to fluctuations in recruitment and fishing mortality

Francis (2011) Data Weighting Method

- Purpose:
  - Initial: to investigate whether effective sample sizes of fishery length comps were reasonable relative to effective sample sizes of survey composition data
  - To assign weights to composition data sources that account for the influence of intra-year correlations in length or age comps that are not explicitly modeled, to avoid preventing the model from fitting the biomass index well
- Examples of correlations not in the model: time-varying selectivity, time- and age-varying natural mortality
- Background:
  - Length and age comp data are often overdispersed relative to the variance assumed by the multinomial likelihood in the model
  - McAllister and Ianelli (1997), Appendix 2: calculates weights to account for overdispersed data relative to variance of the multinomial, ignores correlations
  - Pennington and Volstad (2004): Intra-haul correlation lowers effective sample size
    - E.g. fish of similar ages or lengths are often caught together in a haul
    - The precision of the mean lengths or ages based on a sample of fish from marine surveys is much lower relative to the precision of the mean length or age based on a random sample of the population
    - Precision for some marine surveys is close to the number of hauls, not number of fish
  - Francis (2011):
    - Same concept as for Pennington and Volstad, (measuring precision of means), except applied to intra-year correlations, rather than intra-haul correlations
    - Same idea as McAllister and Ianelli, but accounts for correlations by comparing variation in mean lengths or ages relative to expected means by year (where means are assumed to be normally distributed)
- Potential alternative: explicitly model time-varying effects that influence proportions at length and age so that residuals are not as correlated

GOA Dover sole residuals from sex-specific von-Bertalanffy models fit to survey data 2001-2015 outside the assessment model.

The blue points are more than 1 residual standard error below the curve and the red points are more than 1 RSE above the curve.