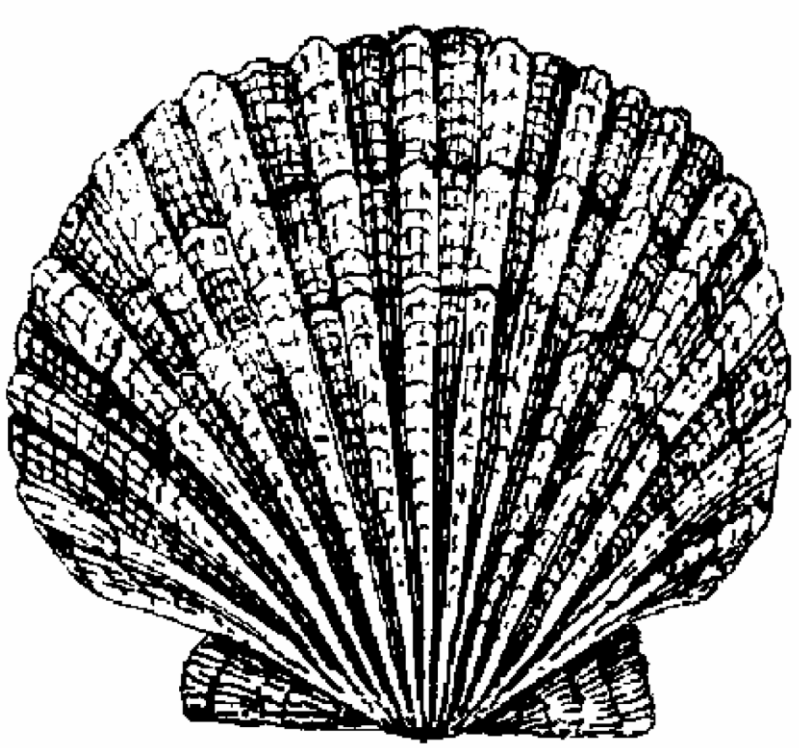
Size and Age Structured Modelling of Weathervane Scallops Using Stock Synthesis

2022 SAFE (Section 9)

Tyler Jackson and Jie Zheng
2022 SPT Meeting
Feb, 16 (via Zoom)



History of Scallop Stock Assessment Modelling

Bechtol (2000) – Age-structured assessment of Kamishak District (KAM), 1983-1997 fishery and ADF&G dredge survey data (ADF&G, RIR)

Zhang (2015) – Update to Bechtol (2000) assessment, 1985-2012 (SPT presentation)

Zheng (2018) – Stock Synthesis age- and size-structured assessment of Kamishak District, 1983 – 2015

Objectives

1) Update previous work by Zheng (2018)
   - Move to Stock Synthesis v3.30
   - Included 2018 ADF&G dredge survey data

2) Apply SS model framework to Kodiak Shelikof District (KSH)

Stock Synthesis

Generalized, ‘integrated analysis’ modelling framework by (Methot and Wetzel 2013) – see supplementary info for full technical description

Implemented in AD Model Builder (ADMB) (Fournier et al. 2012)

Used extensively in North Pacific and West Coast groundfish stocks (well documented)

https://vlab.noaa.gov/web/stock-synthesis/home

Biological Assumptions (Scallop Specific)

1. Males and females are combined, sex ratio is 50/50
2. Spawning occurs between August – October
   - *Should be May – June (Hennick 1970)*
3. Egg production (i.e. fecundity) = spawning biomass
4. LvB growth (Schnute 1981) from ages 0 – 18
5. Round weight ~ shell height (SH) (allometric)
6. Maturity ~ SH (logistic)
7. Natural mortality = 0.19 (0.14 – 0.24)

Natural Mortality (*M*)

Hoenig (1983)

$$M = e^{1.44 - 0.982(\ln t_{max})}$$

Then et al. 2015 reviewed numerous empirical estimators of *M* in > 200 fish species

$$M = \frac{5.109}{t_{max}}$$

$$M = e^{1.717 - 1.01(\ln t_{max})}$$

$$M = 4.899 t_{max}^{-0.916}$$

1% rule (used for AK crab stocks)

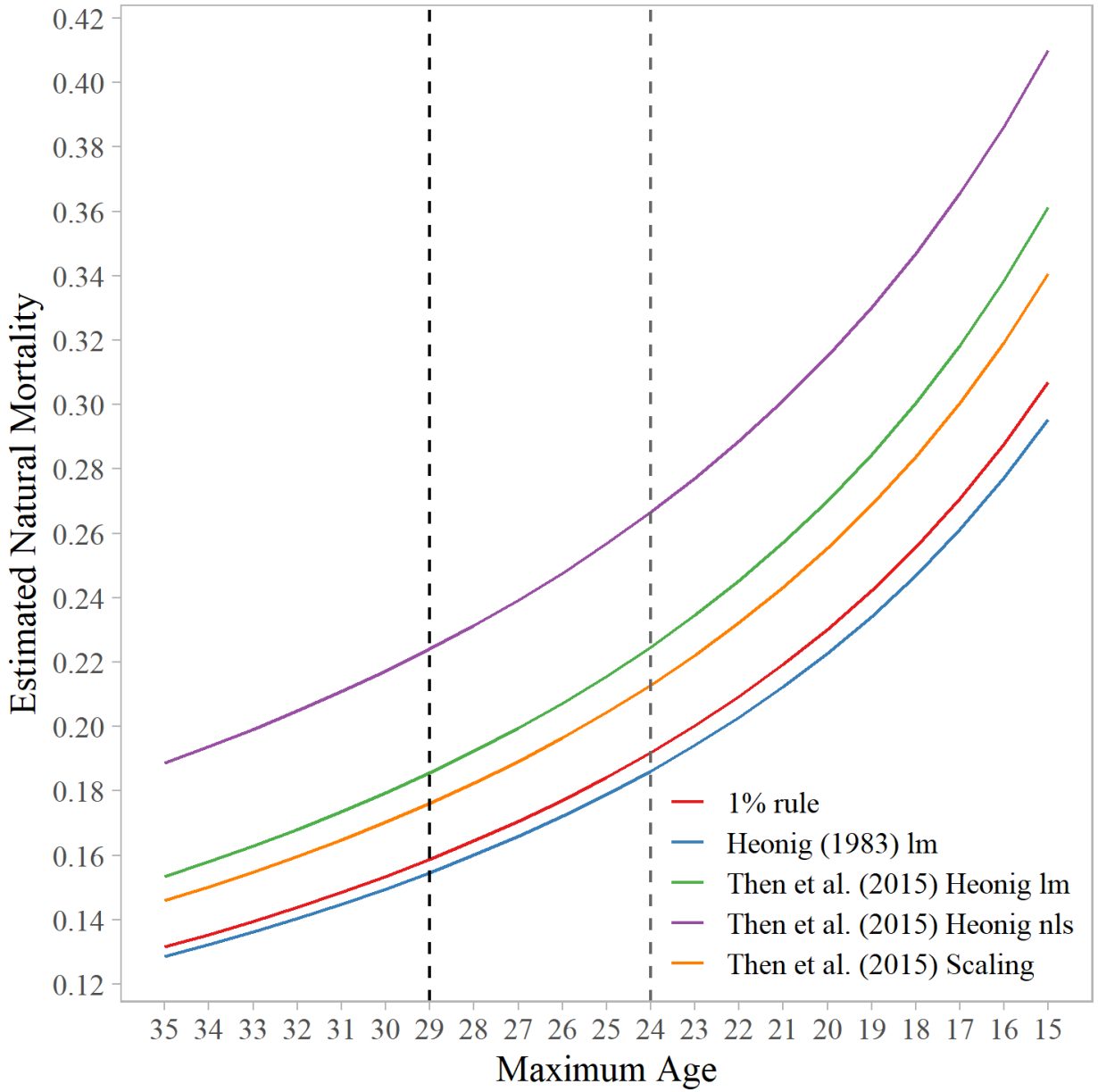
$$M = -\frac{\ln 0.01}{t_{max}}$$

Natural Mortality (*M*)

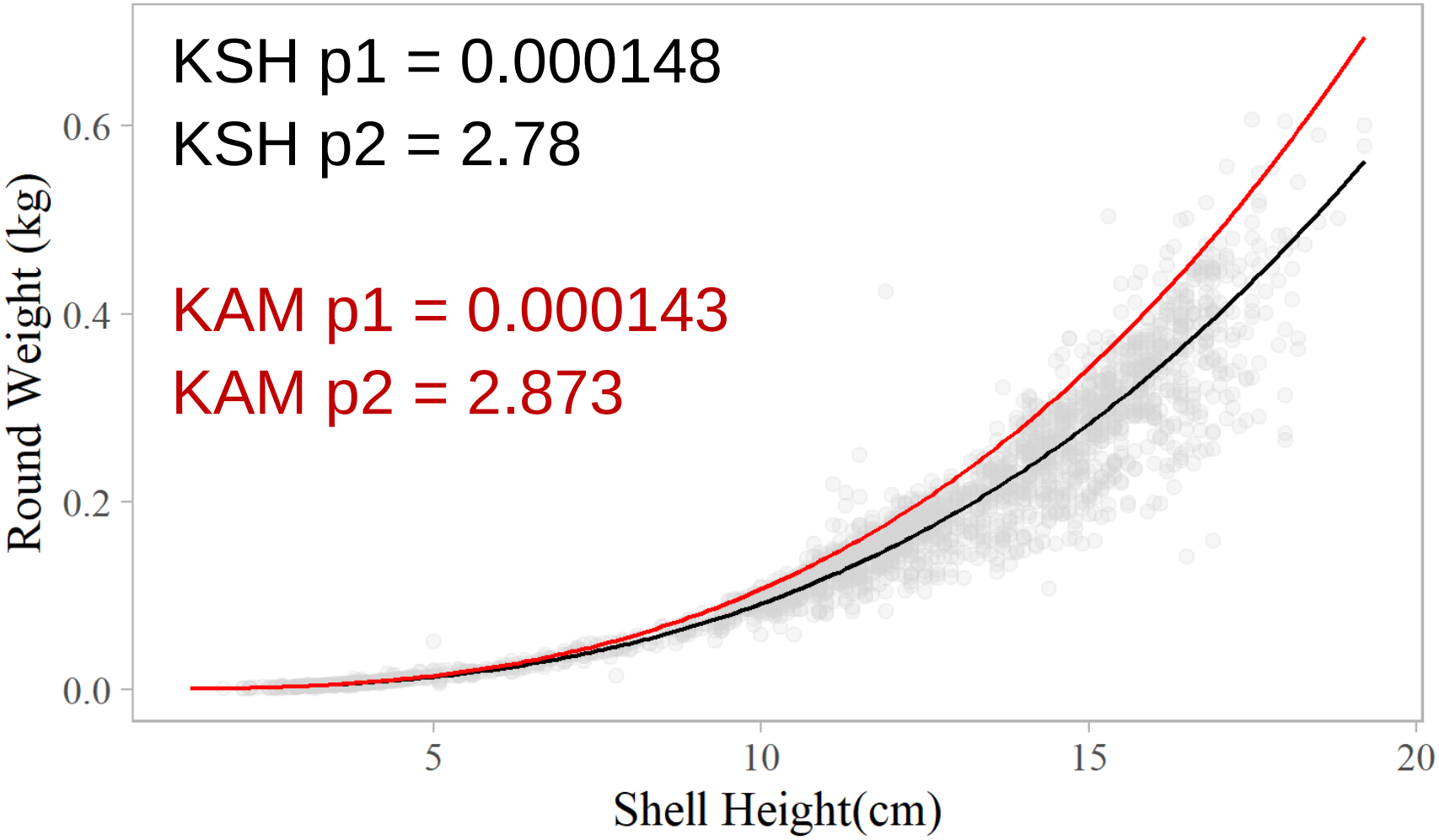
Max age in ADF&G ADU survey ages is 29 yr

Zheng (2018) assumed max age = 24 yr

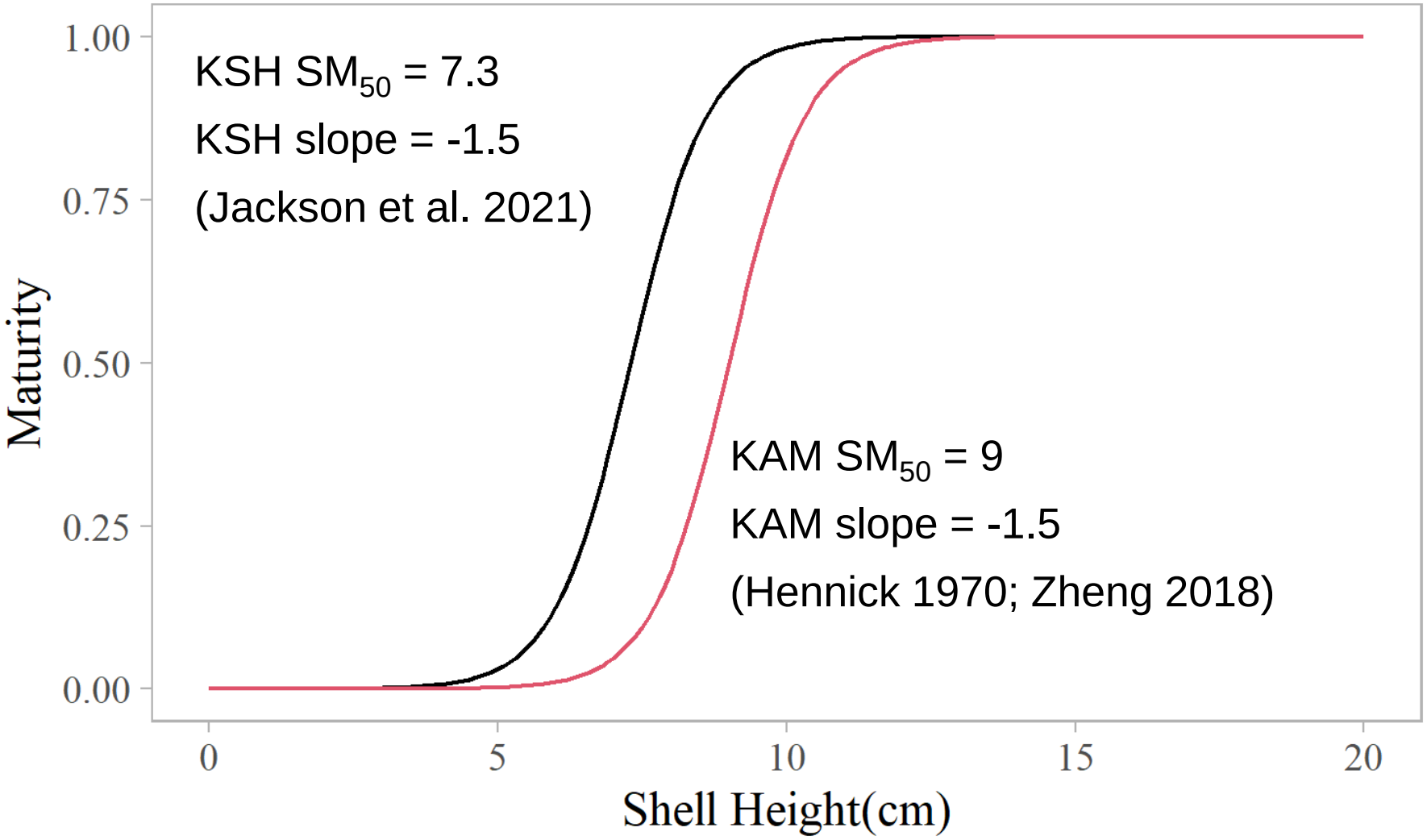
Base *M* = 0.19



Round weight ~ SH



Maturity ~ SH


KSH SM_{50} = 7.3
KSH slope = -1.5
(Jackson et al. 2021)
KAM SM_{50} = 9
KAM slope = -1.5
(Hennick 1970; Zheng 2018)
Maturity
1.00
0.75
0.50
0.25
0.00
0
5
10
15
20
Shell Height(cm)

Recruitment to Age-0

No Stock-Recruit Relationship

$$R_y = e^{R_0 + \tilde{R}_y}$$

$$\tilde{R}_y \sim N(0; \sigma_R^2 = 2)$$

R_0 = Unfished equilibrium recruitment

$\tilde{R}_y$ = Annual recruitment deviation

Catchability and Selectivity

Catchability and selectivity were constant over time

Catchability, Q

- Assumed $Q = 1$ for dredge survey round biomass
- Q is estimated for fishery and trawl CPUE data

Selectivity

- Size selectivity is a logistic function of SH (Methot and Wetzel 2013, Supp. Info.)
- Age selectivity is assumed 1 (i.e., selectivity is only a function of size)

Age and Shell Height Binning

Ages

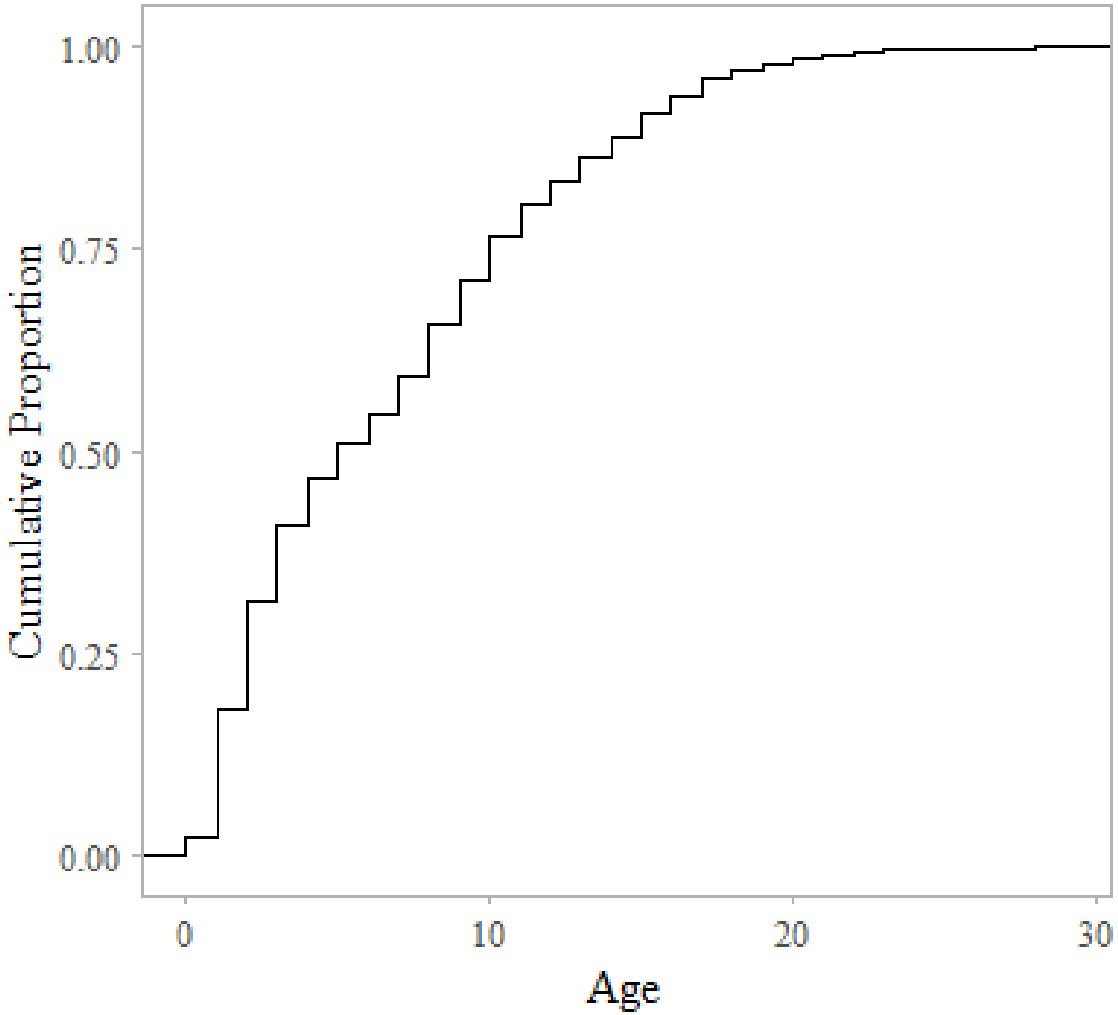
- 0 – 17, 18+

Shell Height

- 33 bins
- 2.1 – 18.1+ cm by 0.5 cm

Effective Sample Sizes for Comps

- min(100, 0.1 * n) - fishery, dredge survey
- min(75, 0.1 * n) - trawl

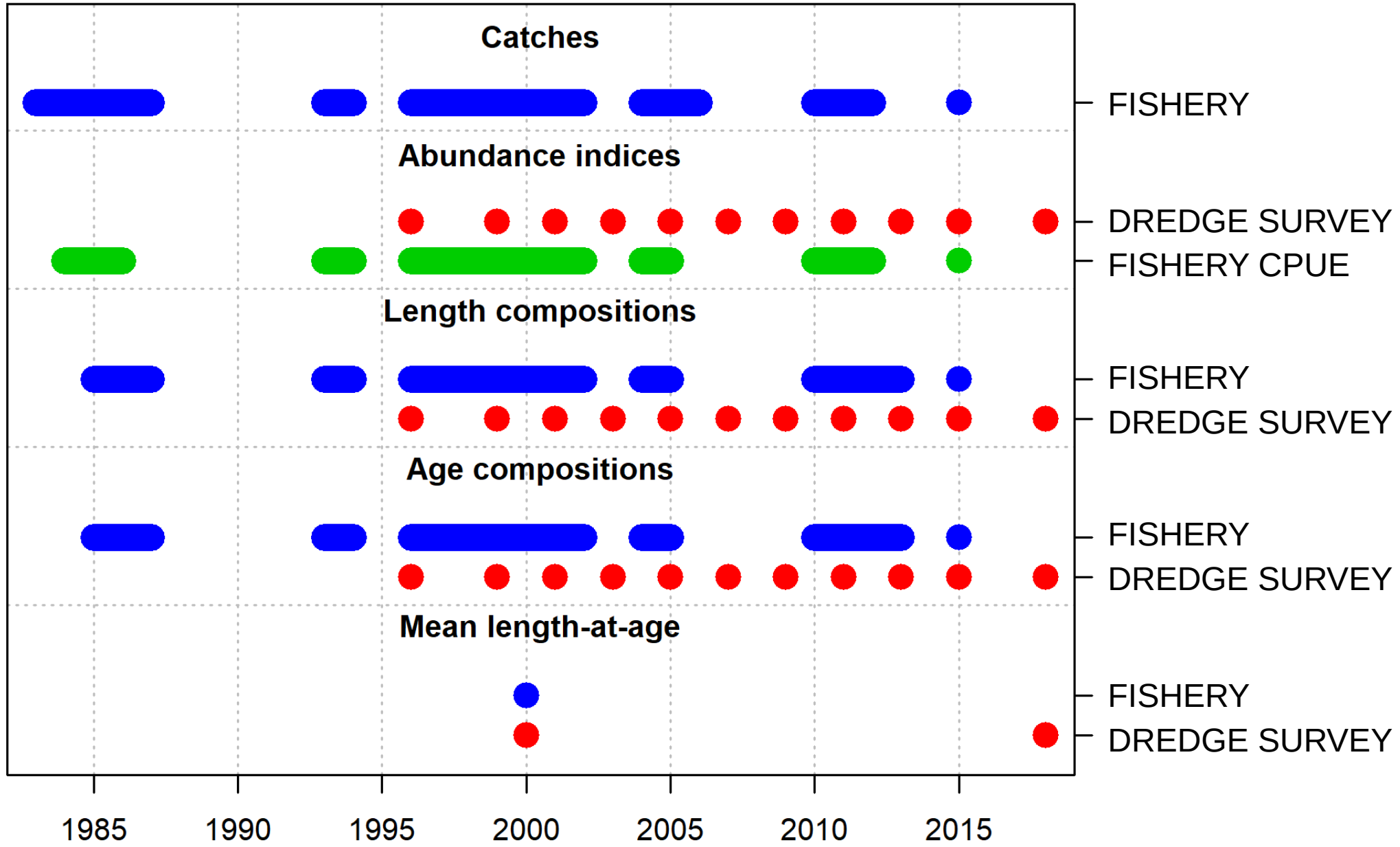


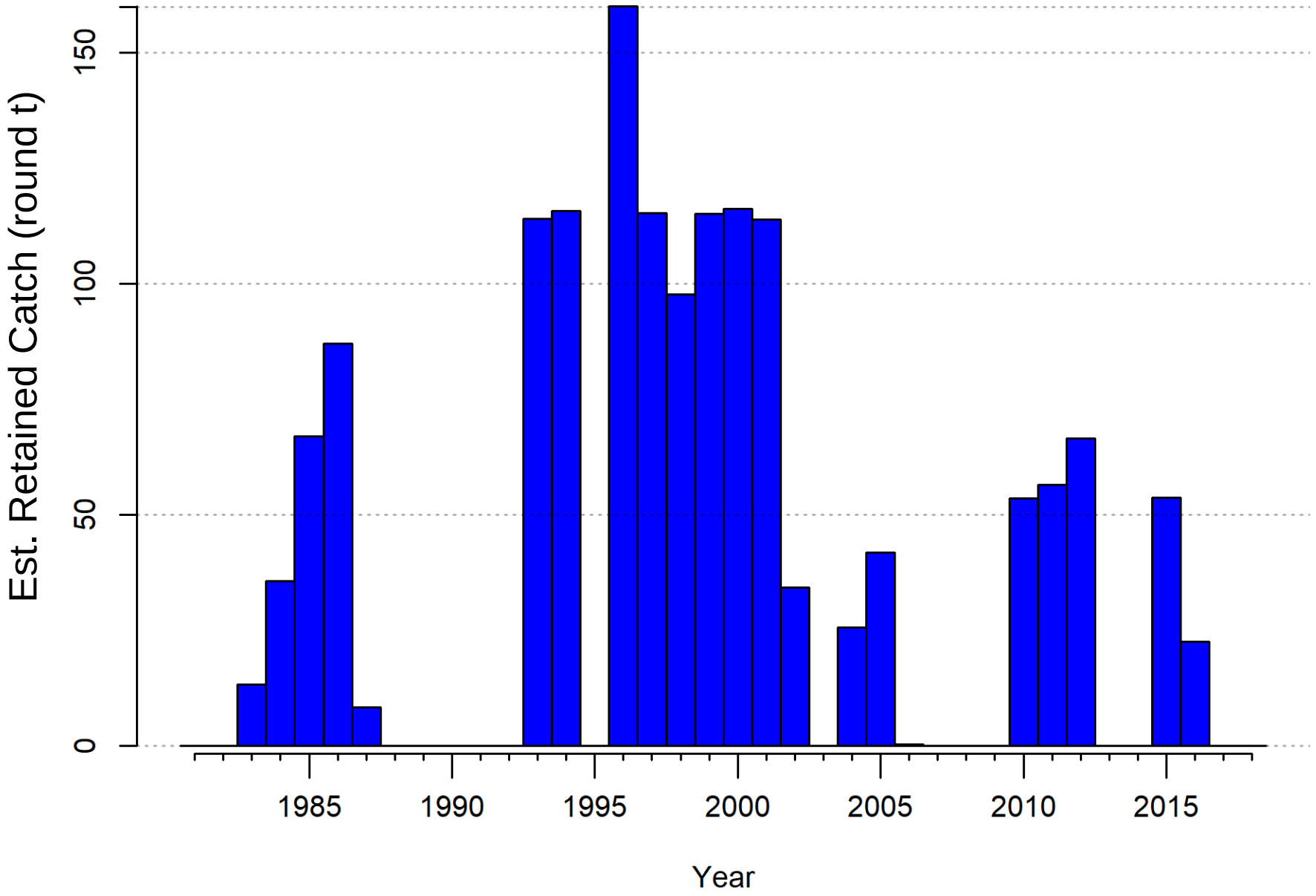
Objective Function

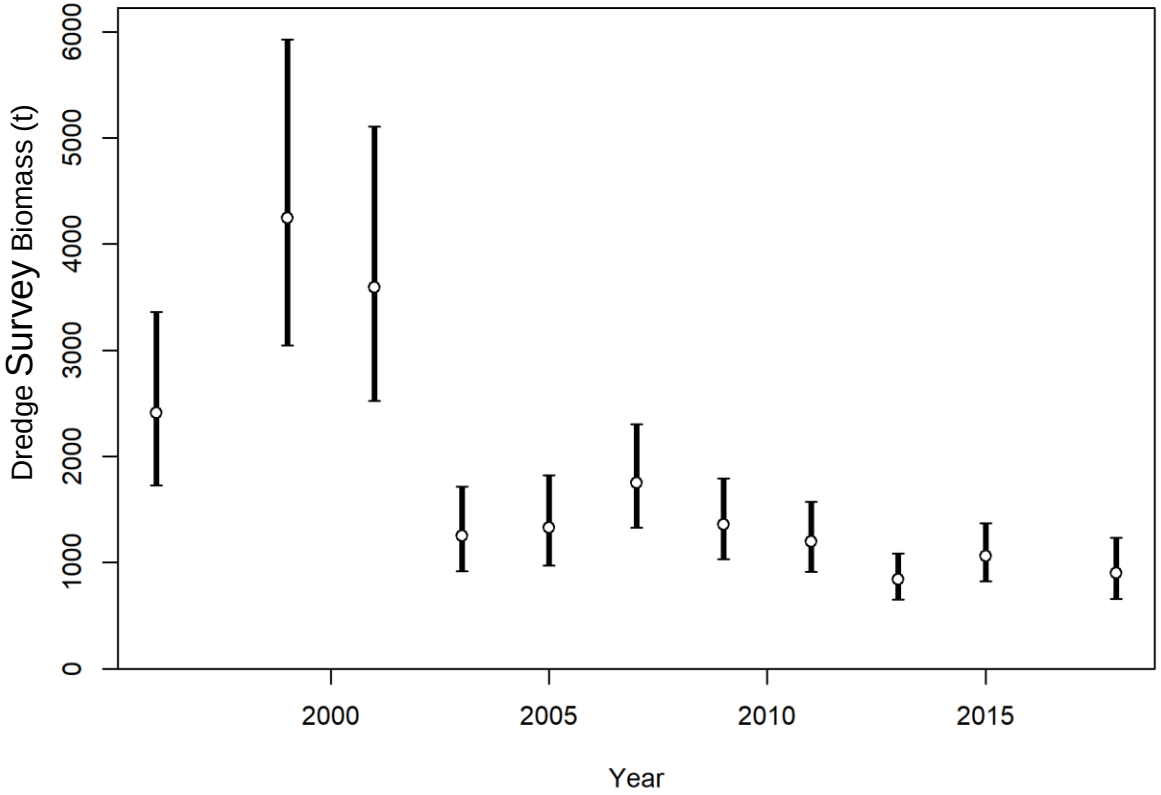
See section 3 (page 13) of Methot and Wetzel (2013) Supp Info for full NLL function

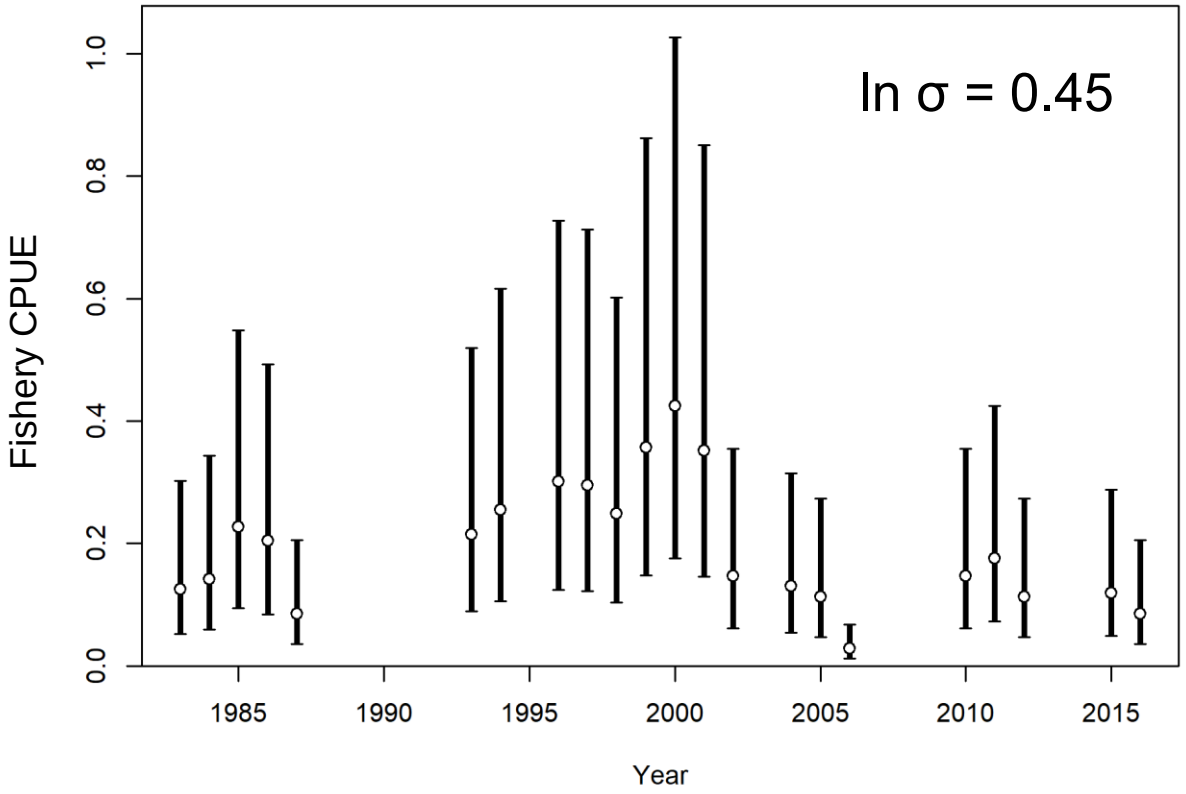
Likelihood Component	Error Distribution
Catch	Lognormal
Biomass Indices	Lognormal
Size and Age Composition	Multinomial
Mean size-at-age	Normal
Recruitment Deviations	Lognormal

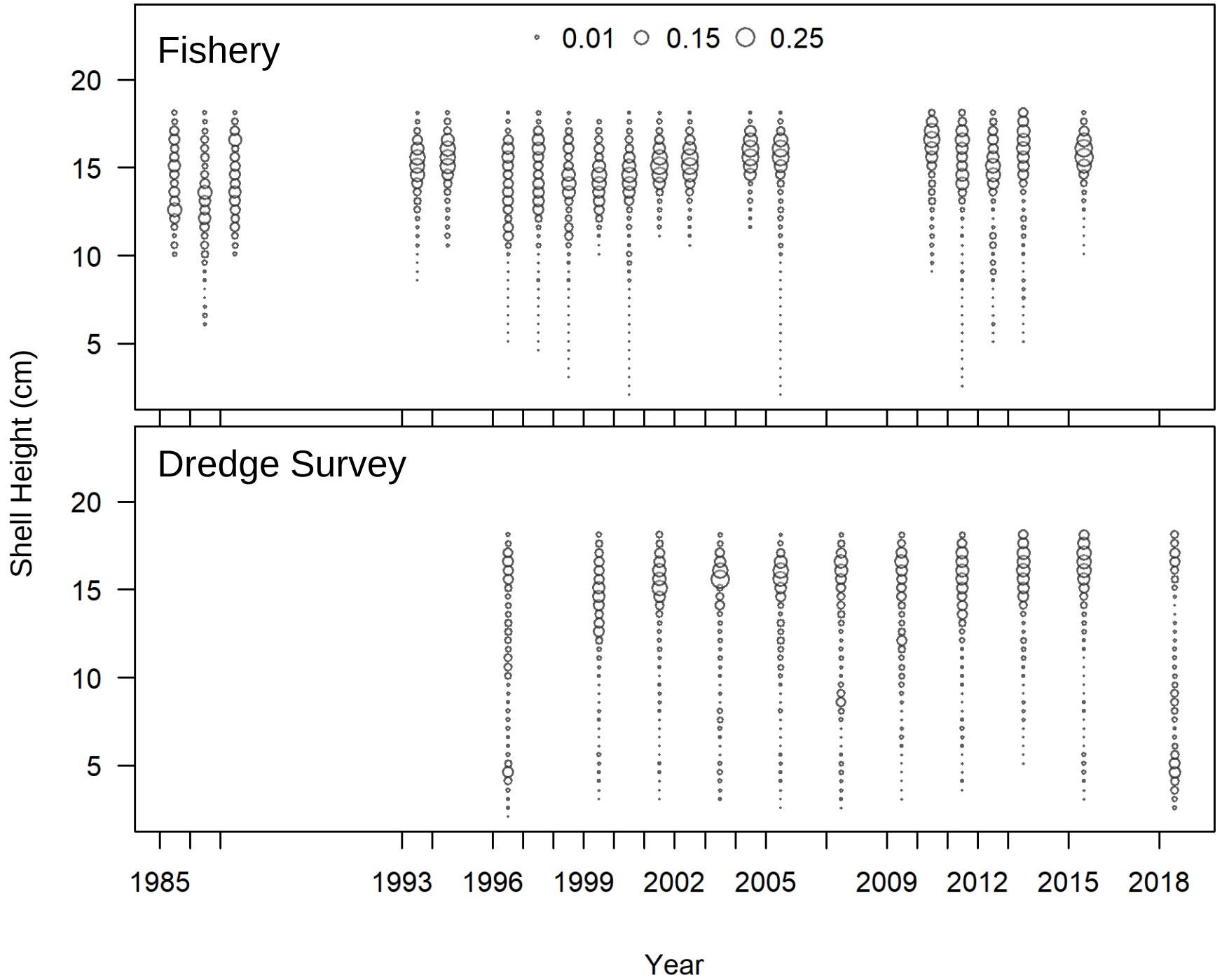
KAMISHAK

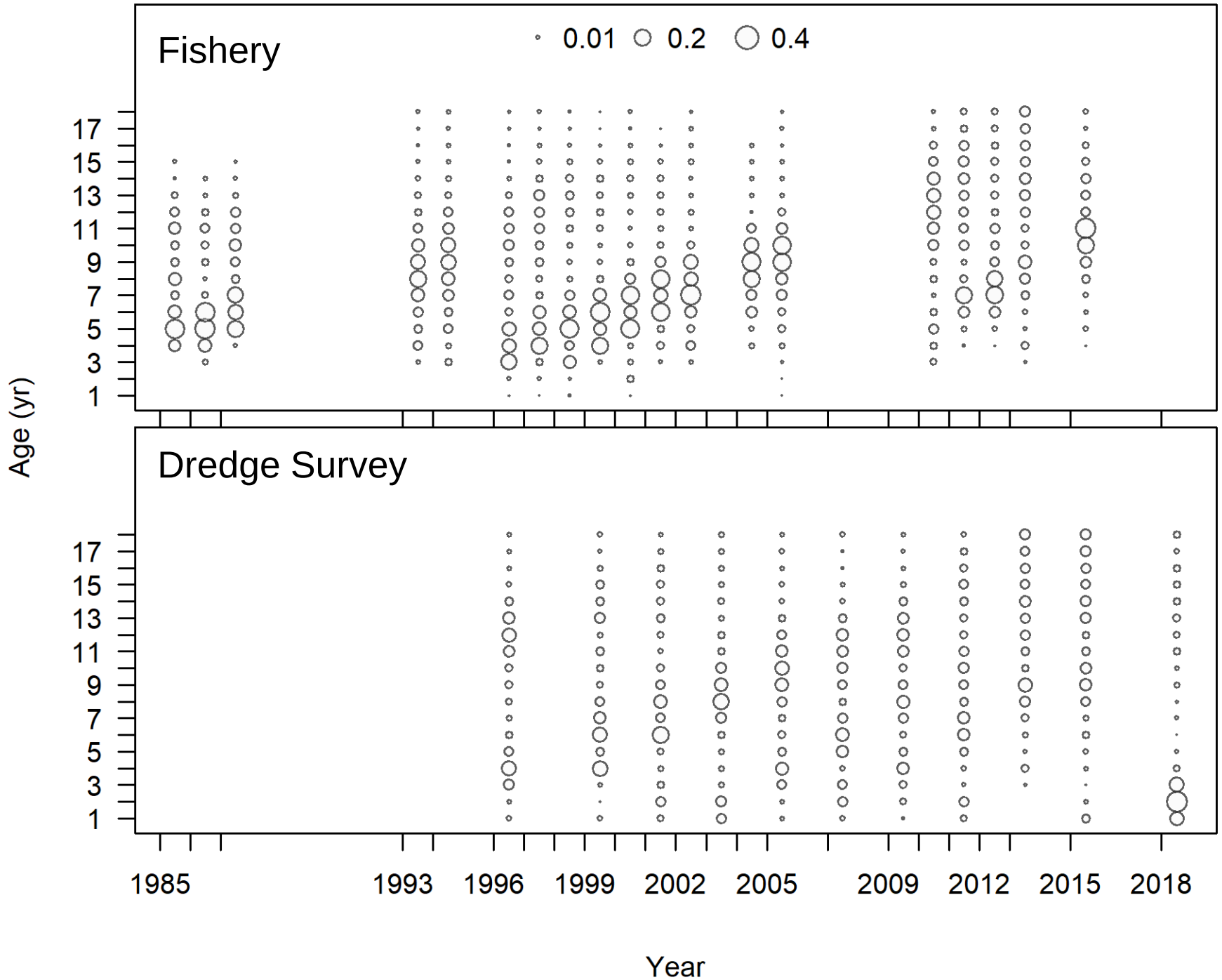

Catches
FISHERY
Abundance indices
DREDGE SURVEY
FISHERY CPUE
Length compositions
FISHERY
DREDGE SURVEY
Age compositions
FISHERY
DREDGE SURVEY
Mean length-at-age
FISHERY
DREDGE SURVEY
1985
1990
1995
2000
2005
2010
2015


Est. Retained Catch (round t)
0
50
100
150
1985
1990
1995
2000
2005
2010
2015
Year


Dredge Survey Biomass (t)
0
1000
2000
3000
4000
5000
6000
2000
2005
2010
2015
Year


ln σ = 0.45
Fishery CPUE
0.0
0.2
0.4
0.6
0.8
1.0
1985
1990
1995
2000
2005
2010
2015
Year


Fishery
0.01
0.15
0.25
Dredge Survey
Shell Height (cm)
20
15
10
5
1985
1993
1996
1999
2002
2005
2009
2012
2015
2018
Year


Fishery
0.01
0.2
0.4
Dredge Survey
Age (yr)
17
15
13
11
9
7
5
3
1
1985
1993
1996
1999
2002
2005
2009
2012
2015
2018
Year

Kamishak Model Scenarios

KAM 22.0: Base model

- **KAM 22.0a**: Base model + M = 0.14 yr-1
- **KAM 22.0b**: Base model + M = 0.17 yr-1
- **KAM 22.0c**: Base model + M = 0.21 yr-1
- **KAM 22.0d**: Base model + M = 0.24 yr-1

Table 9-5	Number of Parameters
Total	65
Growth	5
Virgin Recruitment	1
Recruitment Deviations	54
Catchability	1
Size Selectivity	4

Table 9-6. Negative log likelihood components for Kamishak District models.

	Models				
Likelihood Component	KAM 22.0	KAM 22.0a	KAM 22.0b	KAM 22.0c	KAM 22.0d
Total	615.43	668.783	633.694	600.764	584.912
Fishery Catch	3.64E-12	1.52E-11	7.05E-12	1.47E-12	6.285E-14
Dredge Survey Biomass	9.724	20.532	12.718	8.060	7.347
Fishery CPUE	6.229	11.445	8.123	4.653	2.874
Fishery SH Comp	169.549	175.768	172.110	166.904	162.891
Dredge Survey SH Comp	118.183	119.690	118.647	117.987	118.353
Fishery Age Comp	157.045	170.969	161.914	152.941	148.04
Dredge Survey Age Comp	111.625	119.004	114.337	109.223	106.201
Fishery Size-at-Age	-9.973	-8.826	-9.628	-10.155	-10.125
Dredge Survey Size-at-Age	42.691	47.850	44.586	41.116	39.517
Parameter Priors	1.137	1.210	1.166	1.108	1.066

	Models				
	KAM 22.0	KAM 22.0a	KAM 22.0b	KAM 22.0c	KAM 22.0d
Natural Mortality*	0.19	0.14	0.17	0.21	0.24
Weight-at-SH α*	1.43E-04	1.43E-04	1.43E-04	1.43E-04	1.43E-04
Weight-at-SH β*	2.873	2.873	2.873	2.873	2.873
Size at 50% maturity*	9	9	9	9	9
Maturity slope*	-1.5	-1.5	-1.5	-1.5	-1.5
Log Virgin Rec	7.70524	6.48612	7.17604	8.3598	10.256
SD Log Rec*	2	2	2	2	2
LvB Growth Min SH	1.988	1.901	1.952	2.026	2.086
LvB Growth Max SH	17.059	17.034	17.051	17.065	17.070
LvB *k*	0.253	0.260	0.256	0.250	0.245
CV growth < min SH	0.121	0.118	0.119	0.122	0.124
CV growth > max SH	0.036	0.038	0.037	0.035	0.034
Fishery ln Q	-9.687	-9.032	-9.377	-10.125	-11.693
Fishery Size Sel p1	13.029	12.684	12.882	13.188	13.448
Fishery Size Sel p2	2.961	2.874	2.923	3.000	3.063
Dredge Size Sel p1	17.636	13.240	15.681	20.104	27.476
Dredge Size Sel p2	11.819	11.168	11.599	11.978	12.081

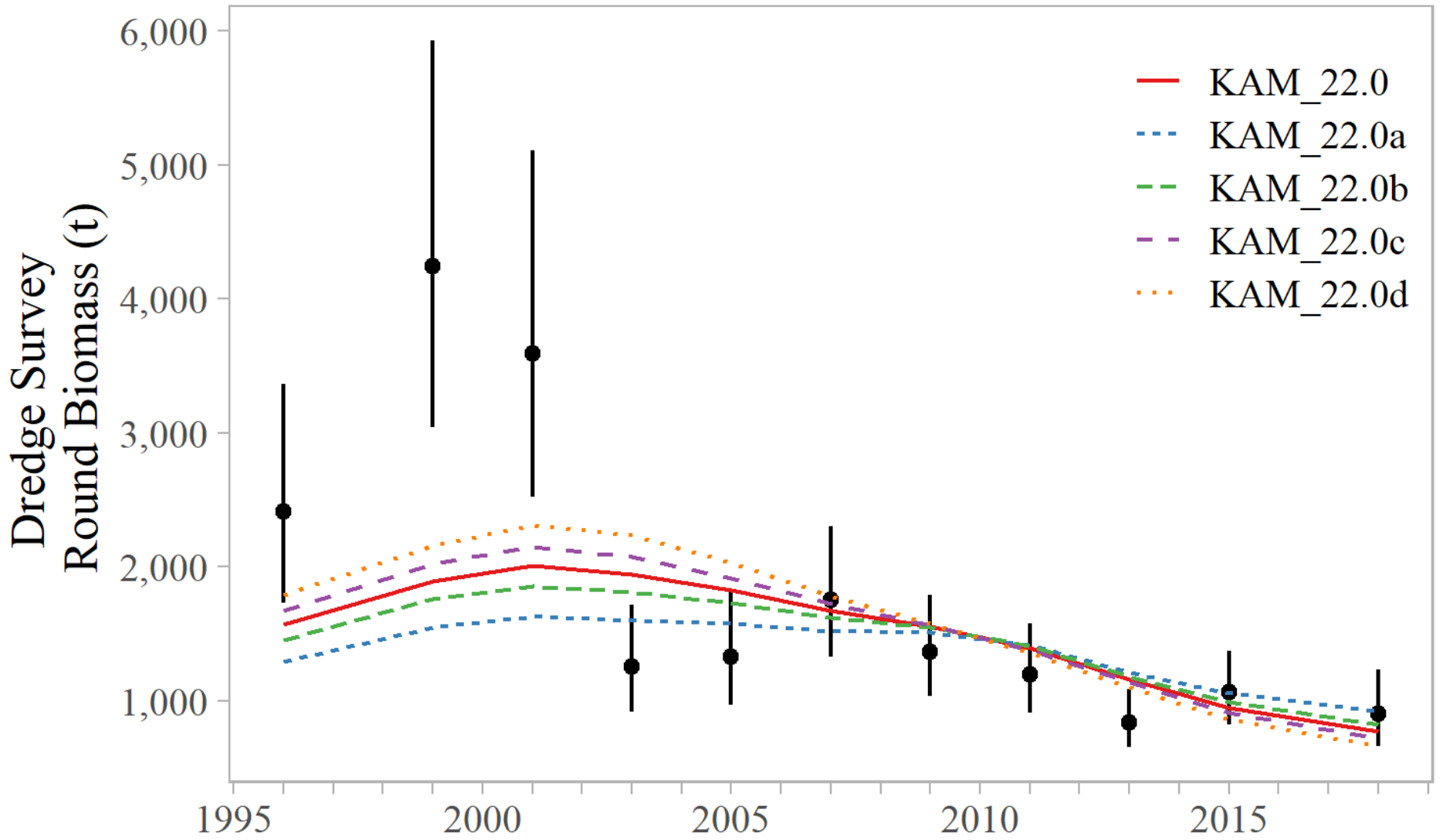

Dredge Survey
Round Biomass (t)
6,000
5,000
4,000
3,000
2,000
1,000
1995
2000
2005
2010
2015
KAM_22.0
KAM_22.0a
KAM_22.0b
KAM_22.0c
KAM_22.0d

Figure 9-1

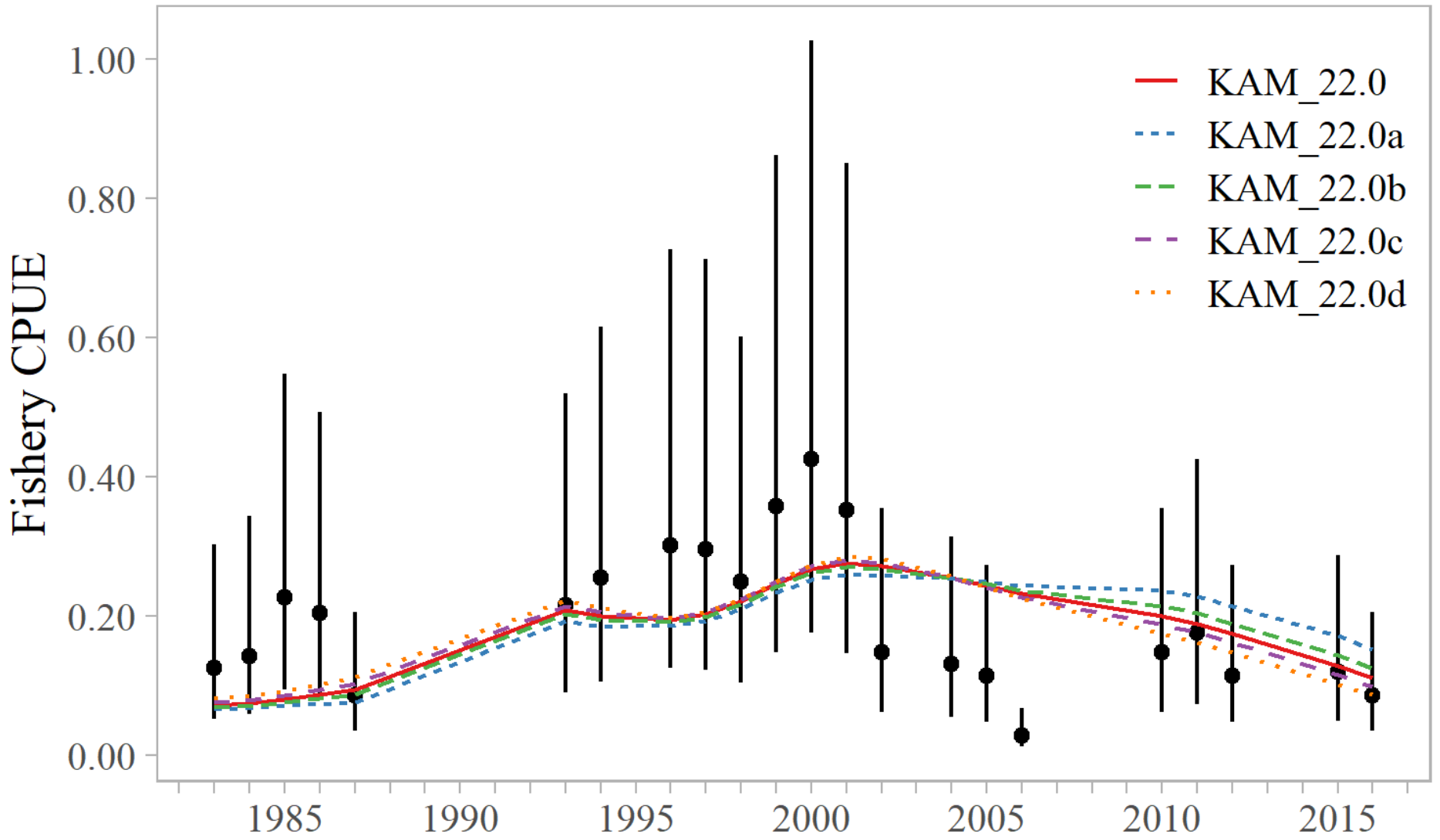

Fishery CPUE
1.00
0.80
0.60
0.40
0.20
0.00
1985
1990
1995
2000
2005
2010
2015
KAM_22.0
KAM_22.0a
KAM_22.0b
KAM_22.0c
KAM_22.0d

Figure 9-2

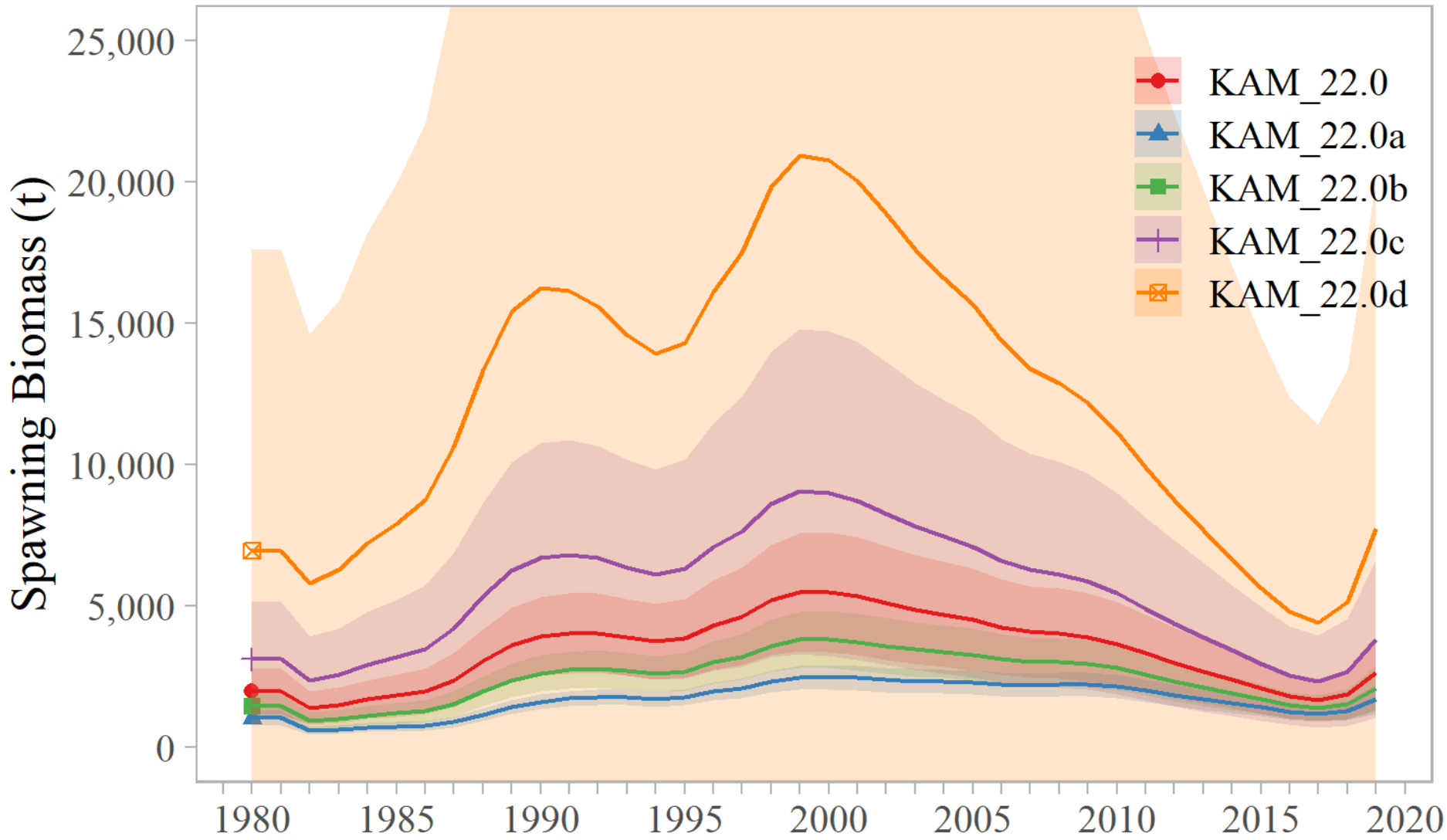

Spawning Biomass (t)
25,000
20,000
15,000
10,000
5,000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
KAM_22.0
KAM_22.0a
KAM_22.0b
KAM_22.0c
KAM_22.0d

Figure 9-3

	Models				
	KSH_22.0	KSH_22.1	KSH_22.1a	KSH_22.1b	KSH_22.2
Log Virgin Rec	7.70524	6.48612	7.17604	8.3598	10.256
Unfished *R* (millions)	2.220	0.656	1.308	4.272	28.453

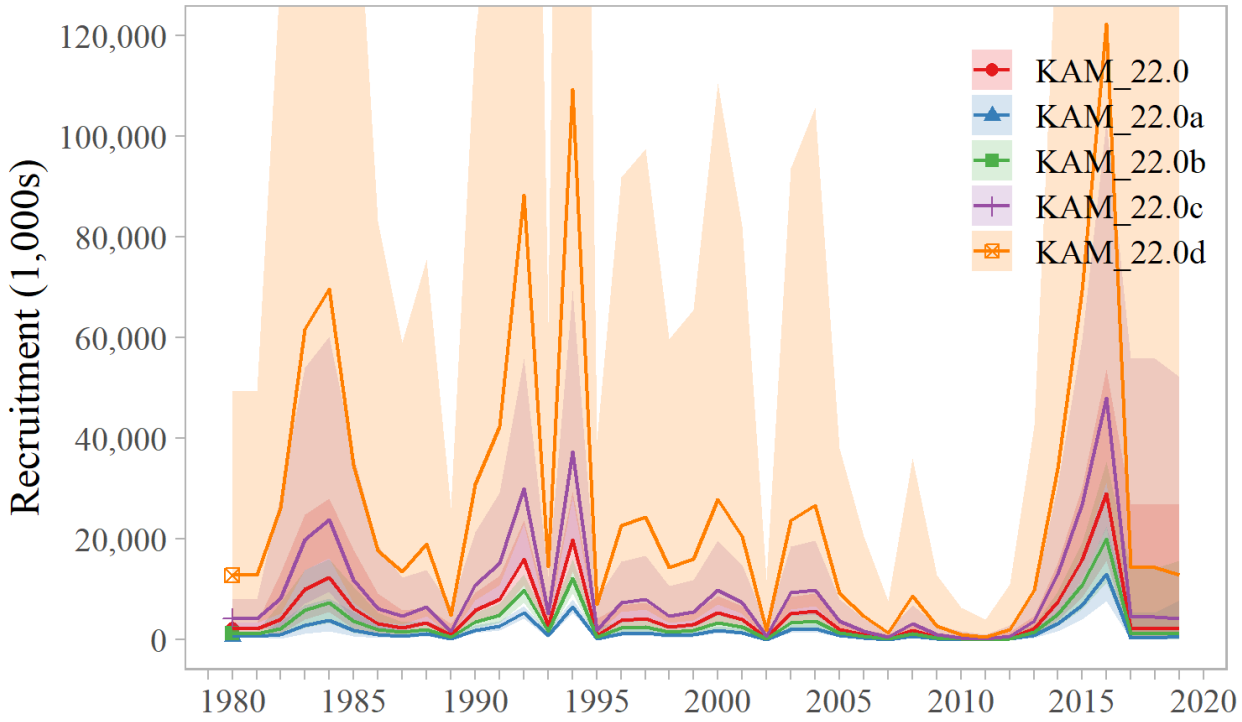


Figure 9-4

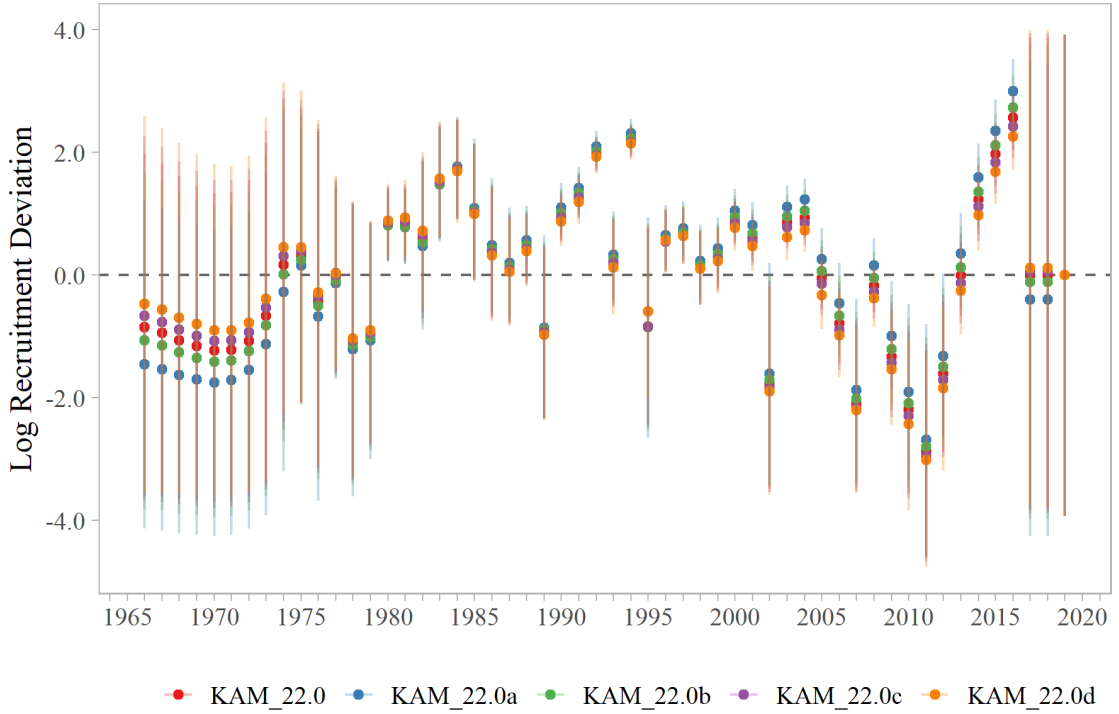


Figure 9-5

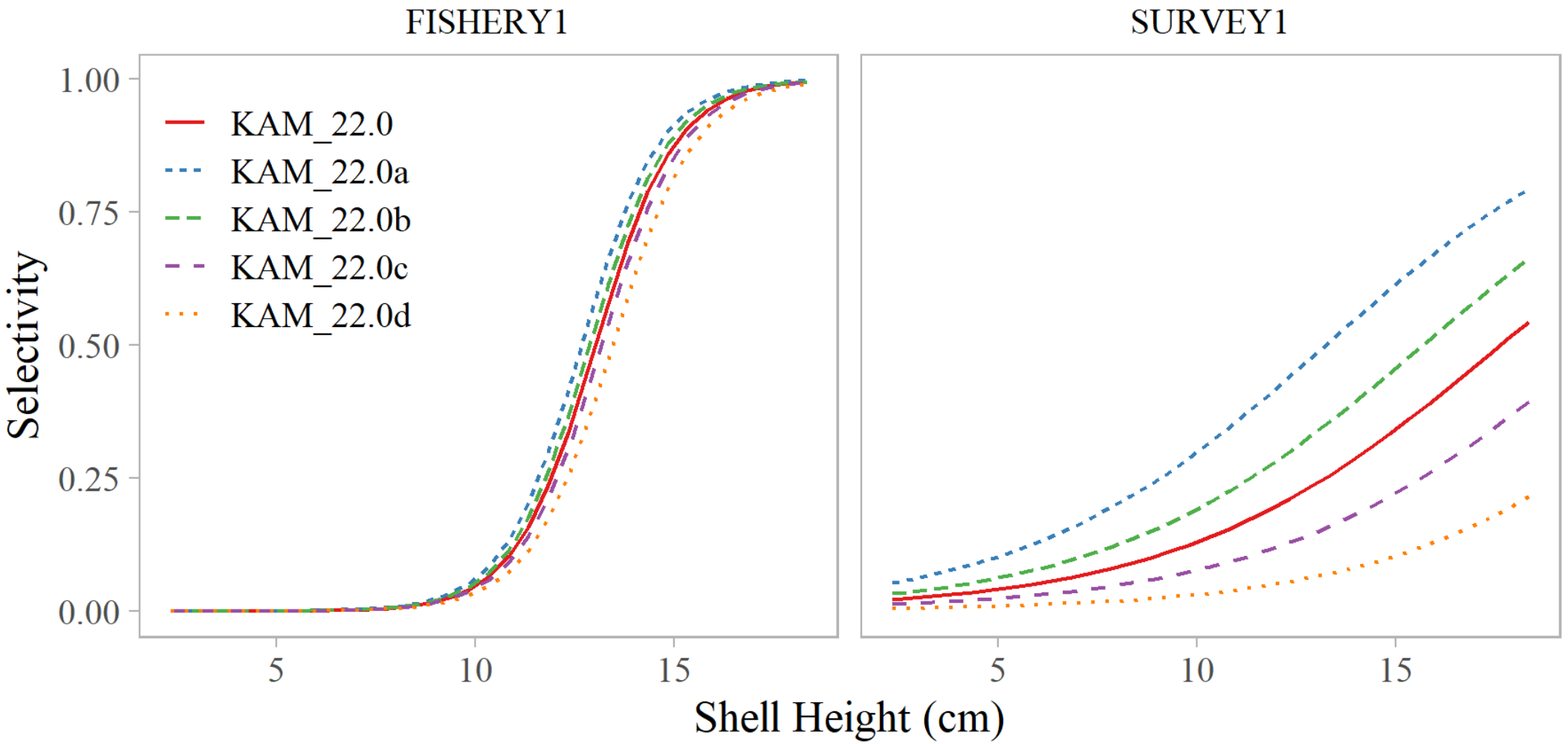

FISHERY1
SURVEY1
1.00
0.75
0.50
0.25
0.00
Selectivity
KAM_22.0
KAM_22.0a
KAM_22.0b
KAM_22.0c
KAM_22.0d
5
10
15
Shell Height (cm)

Figure 9-10

Fishery Size Composition

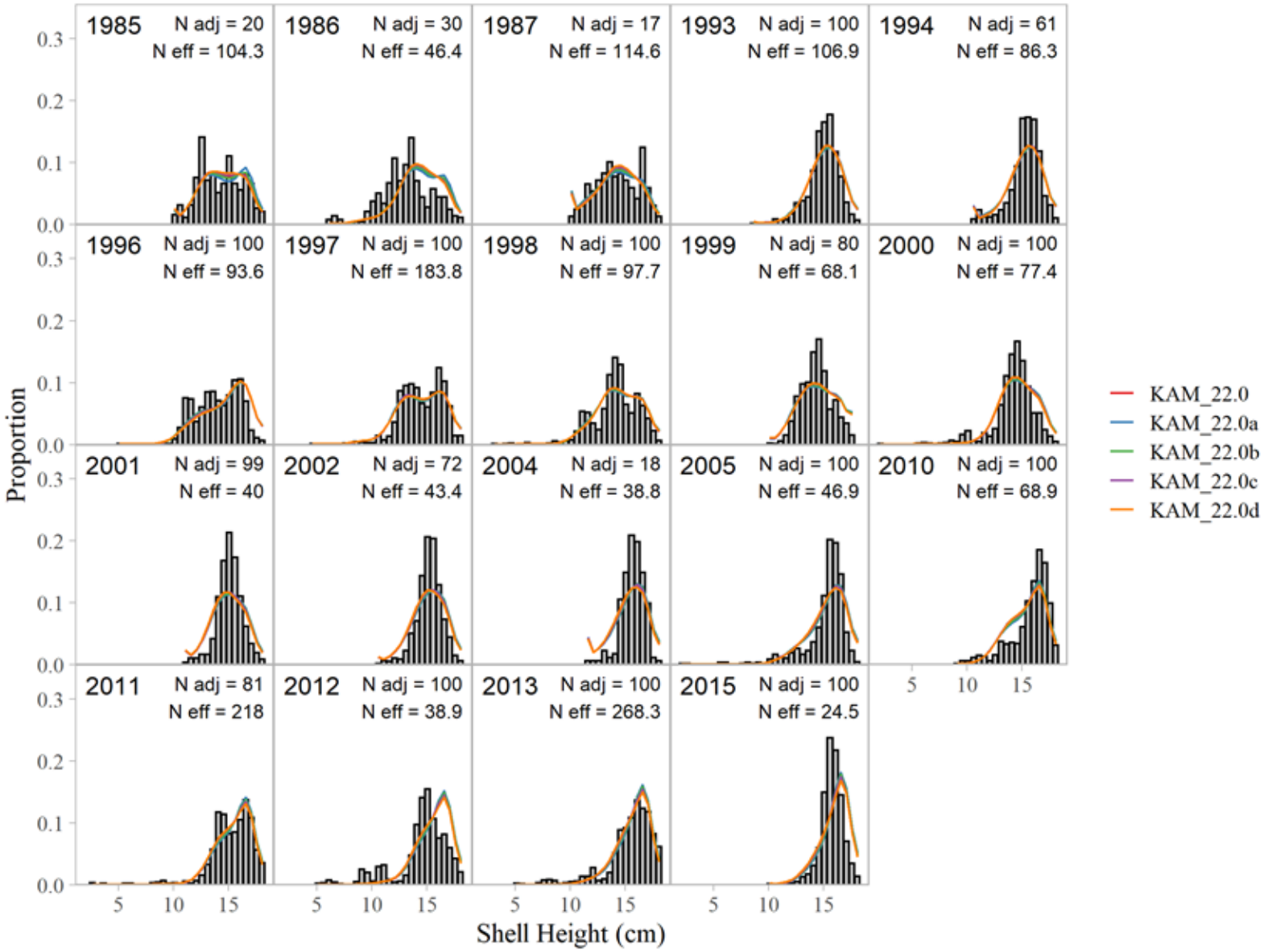
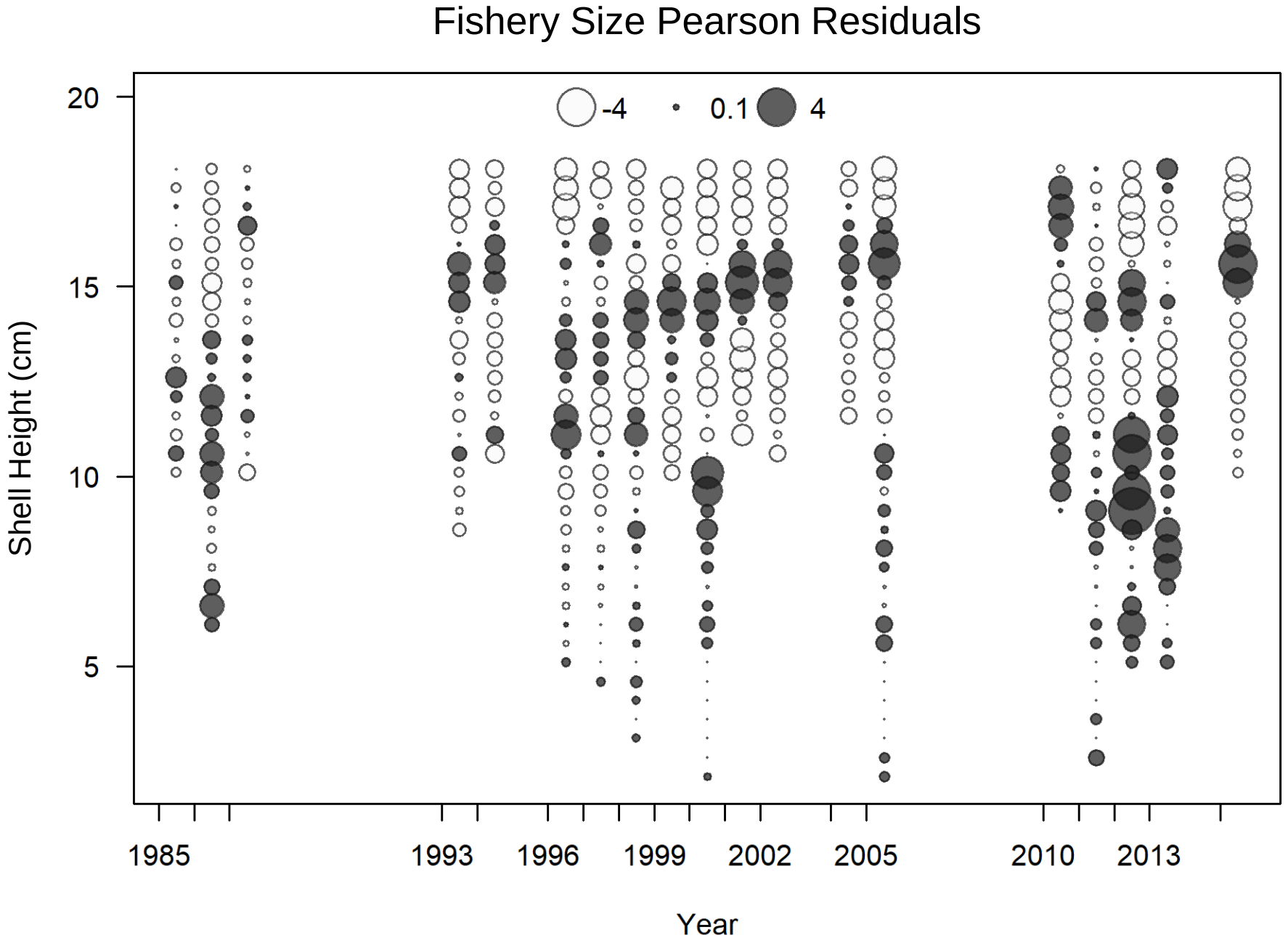


Figure 9-6


Fishery Size Pearson Residuals
-4
0.1
4
20
15
10
5
Shell Height (cm)
1985
1993
1996
1999
2002
2005
2010
2013
Year

Dredge Survey Size Composition

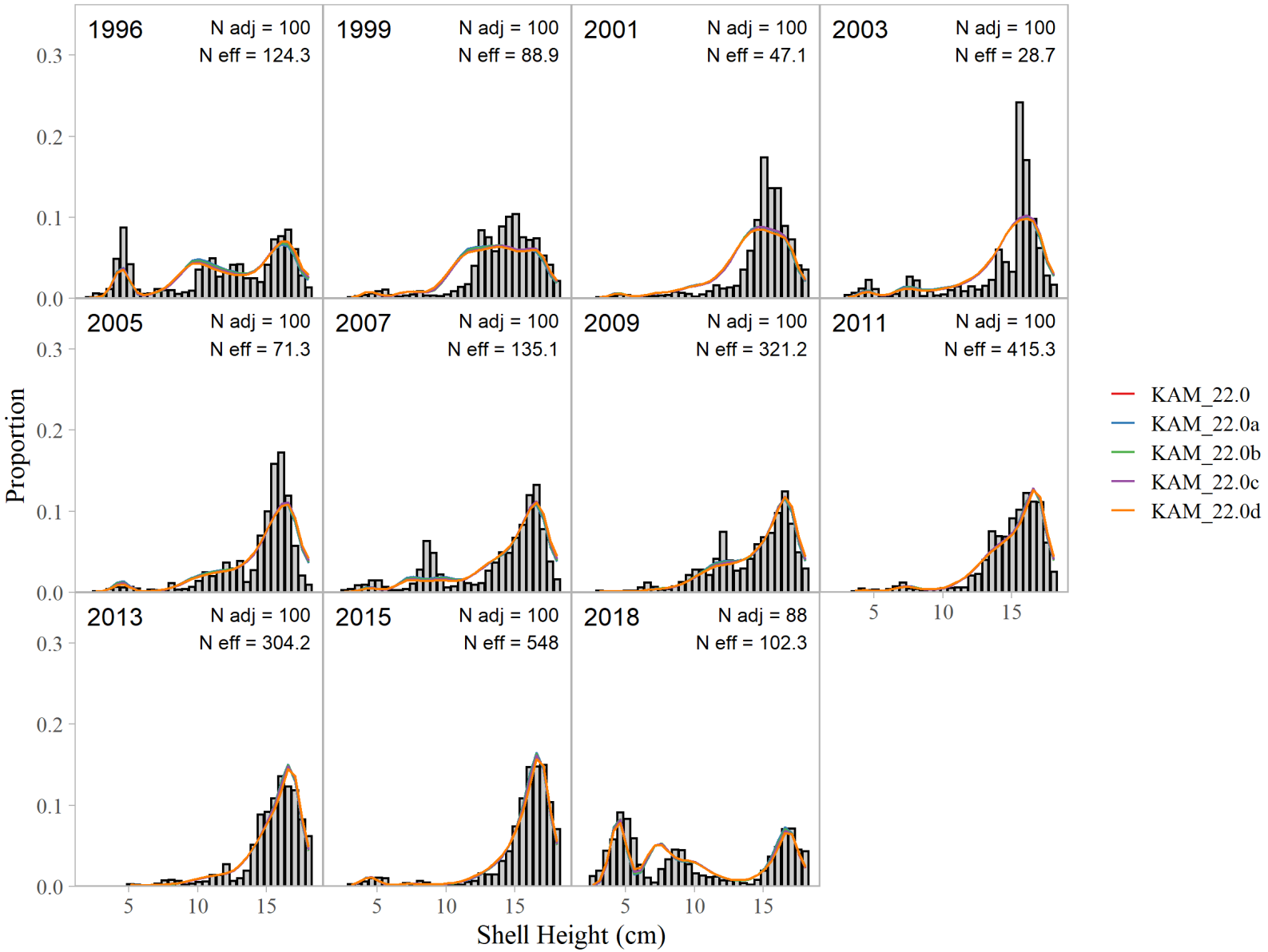
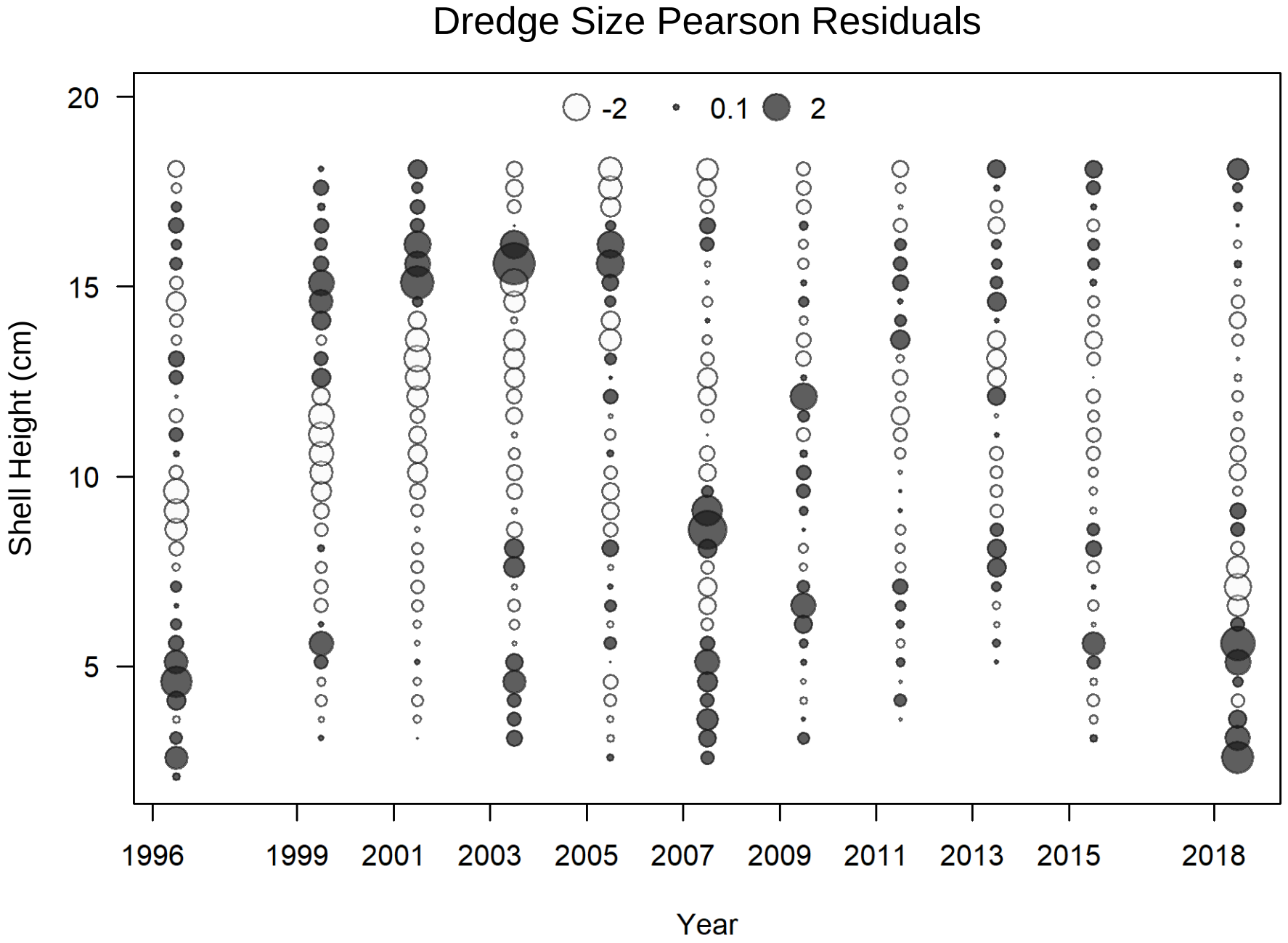


Figure 9-7


Dredge Size Pearson Residuals
-2
0.1
2
Shell Height (cm)
20
15
10
5
1996
1999
2001
2003
2005
2007
2009
2011
2013
2015
2018
Year

Fishery Age Composition

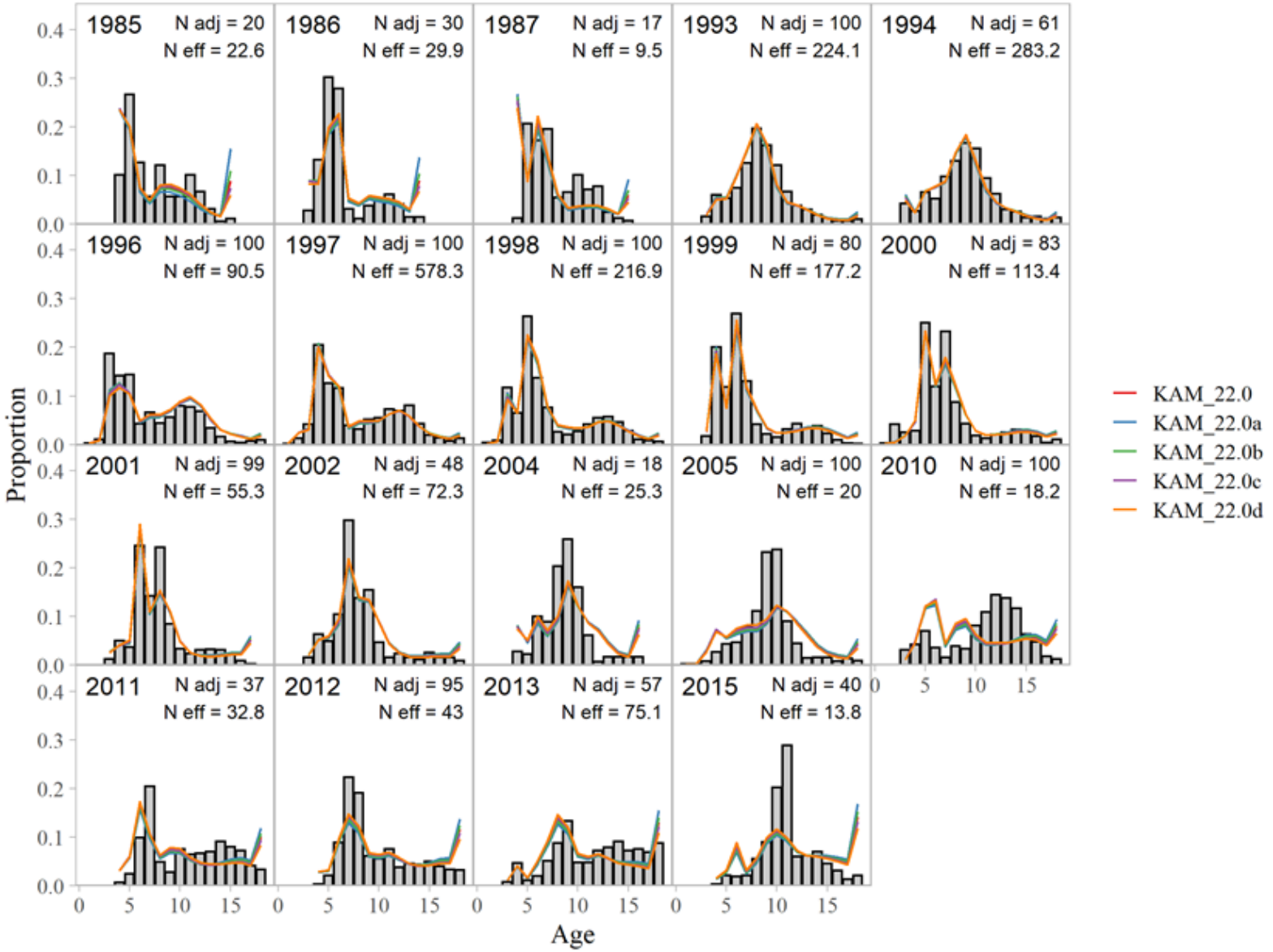
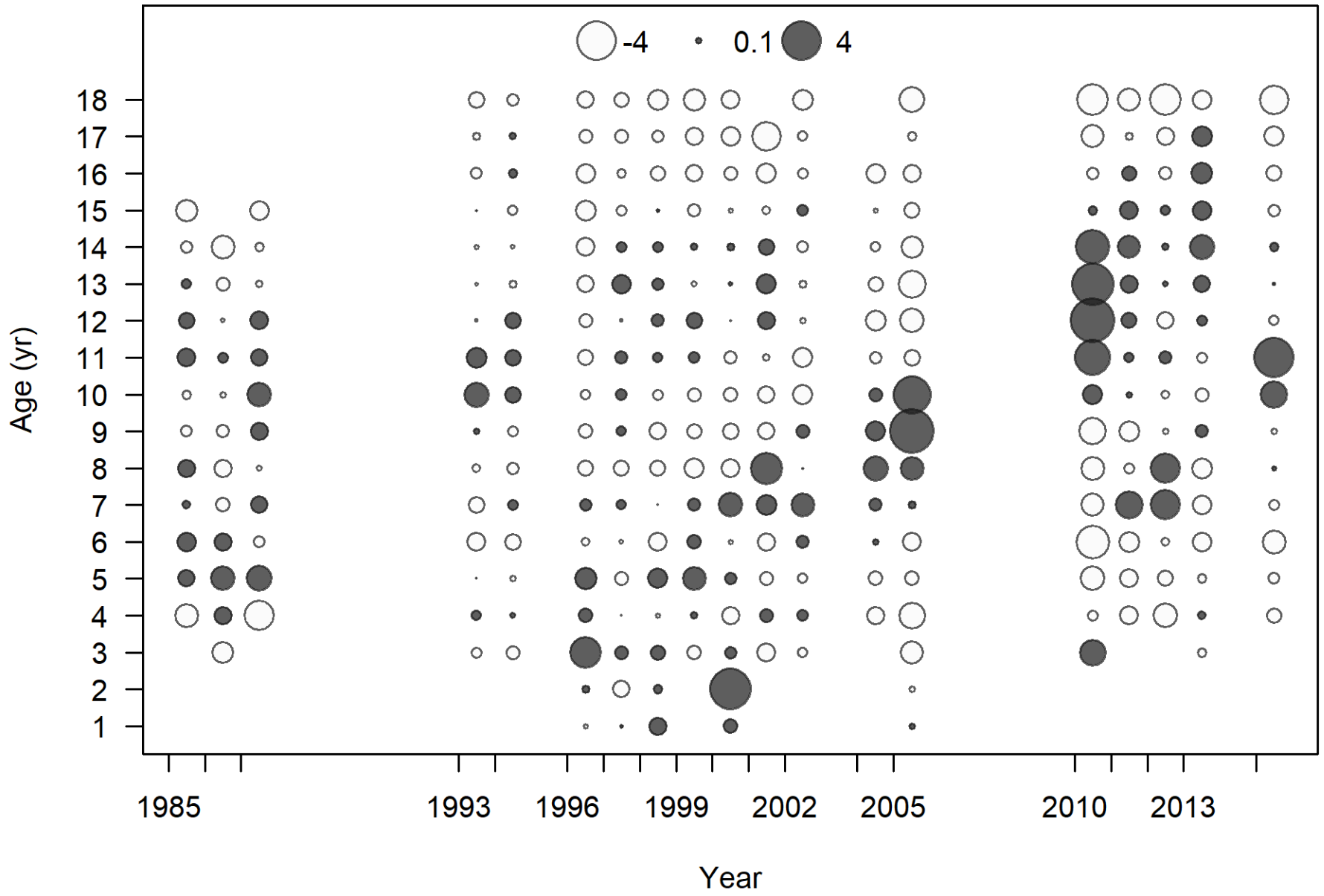


Figure 9-11

Fishery Age Pearson Residuals



Dredge Survey Age Composition

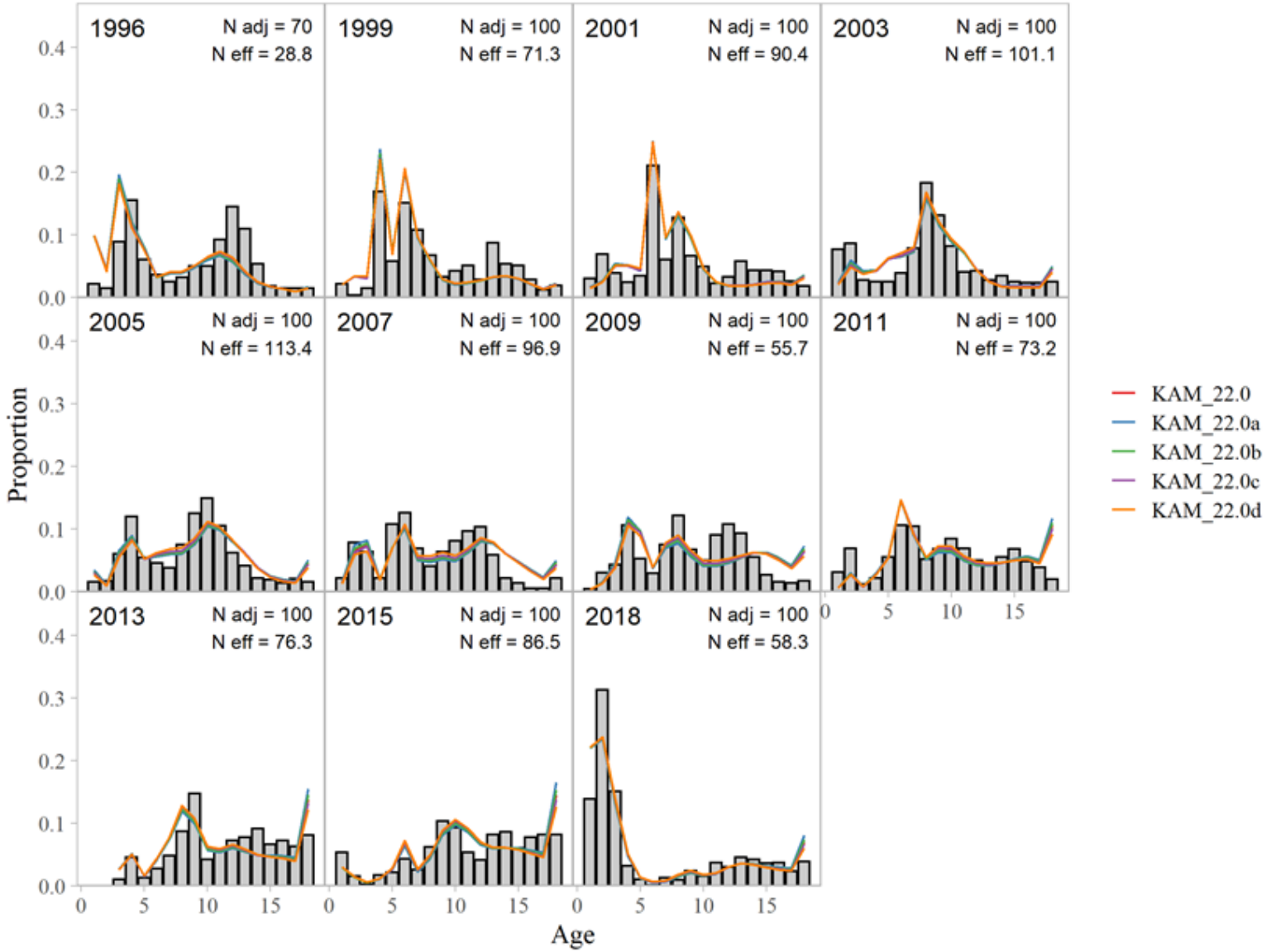
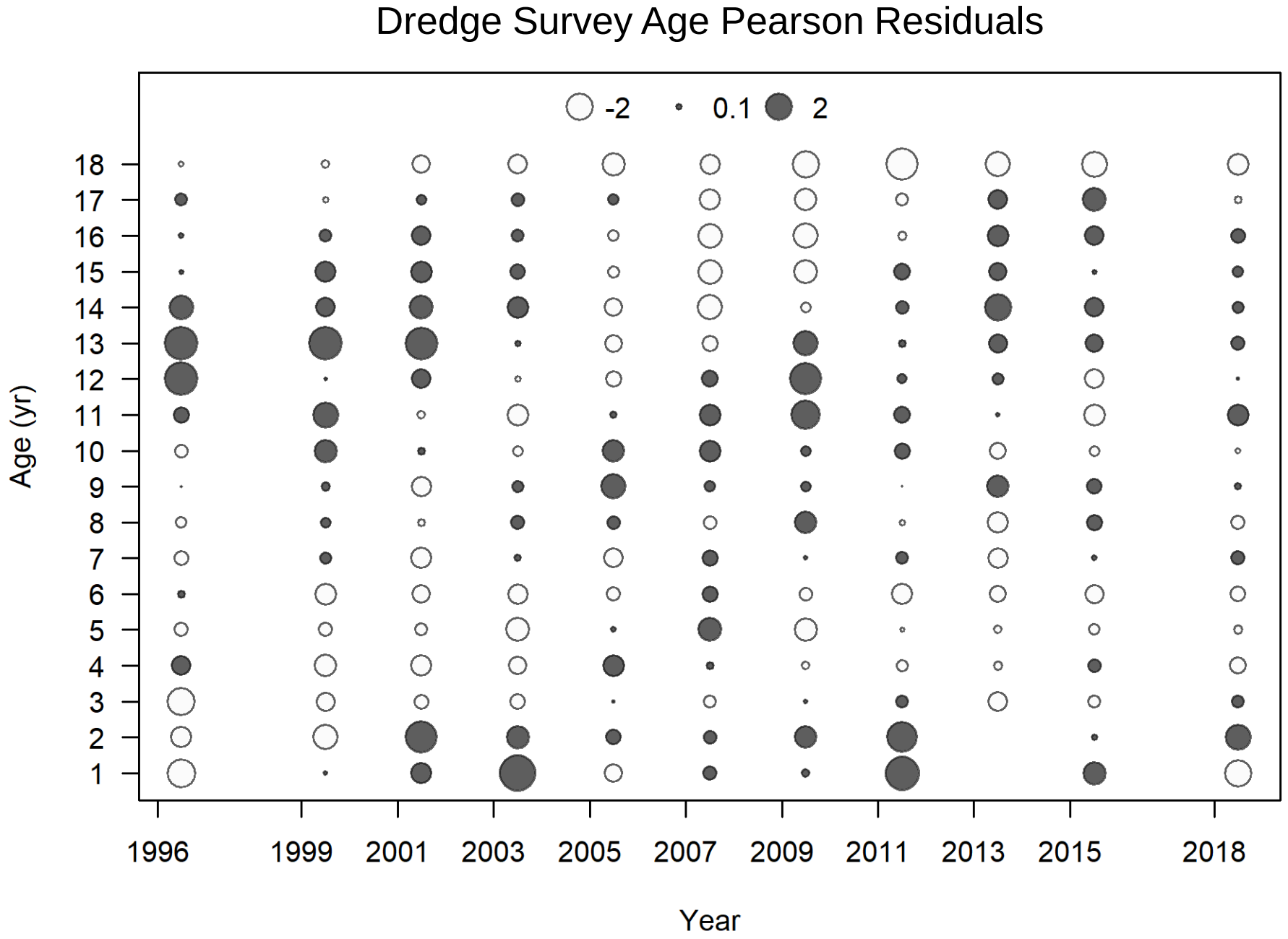


Figure 9-12


Dredge Survey Age Pearson Residuals
-2
0.1
2
Age (yr)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1996
1999
2001
2003
2005
2007
2009
2011
2013
2015
2018
Year

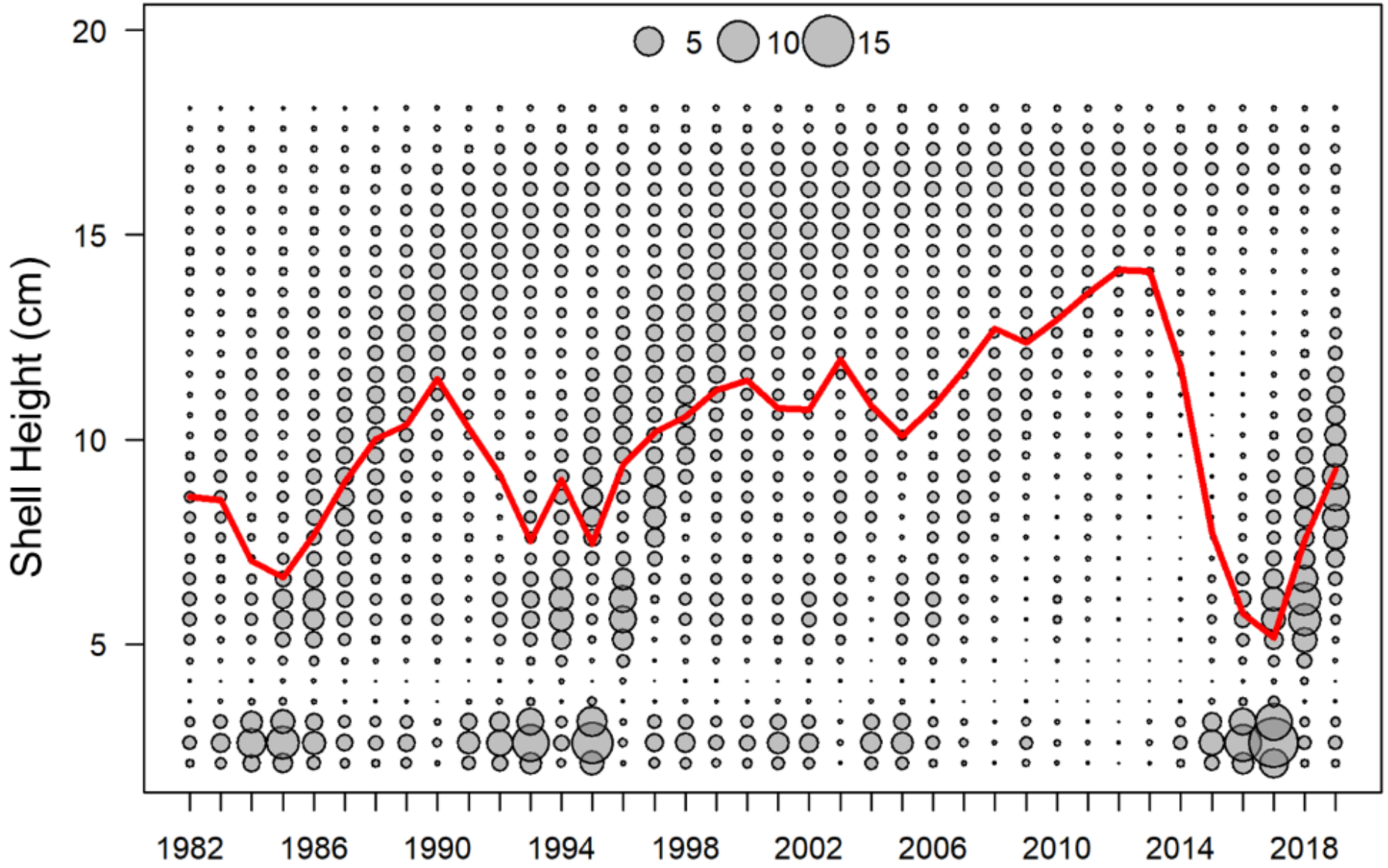

Shell Height (cm)
20
15
10
5
5
10
15
1982
1986
1990
1994
1998
2002
2006
2010
2014
2018

Figure 9-15

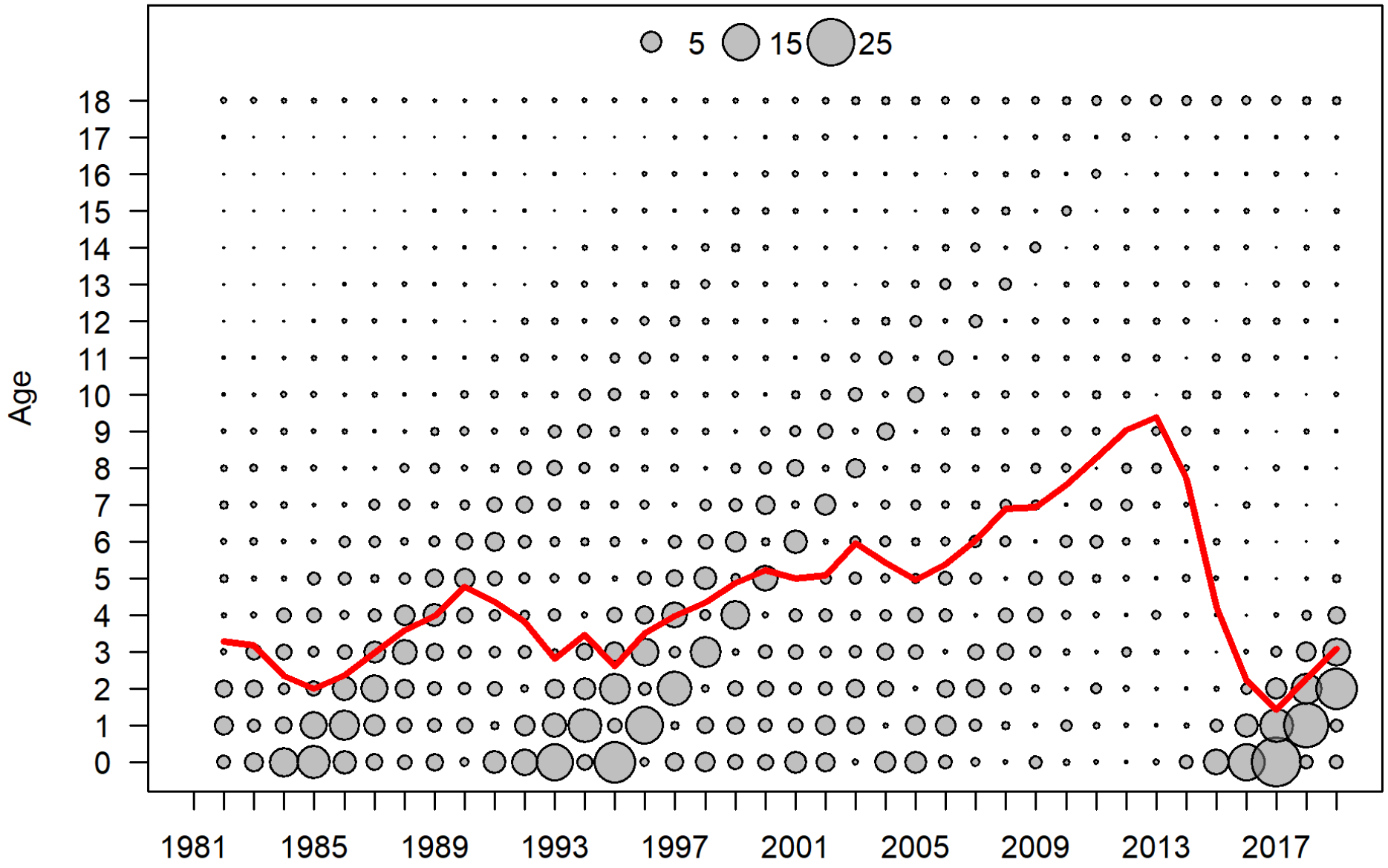

5
15
25
Age
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1981
1985
1989
1993
1997
2001
2005
2009
2013
2017

Figure 9-16

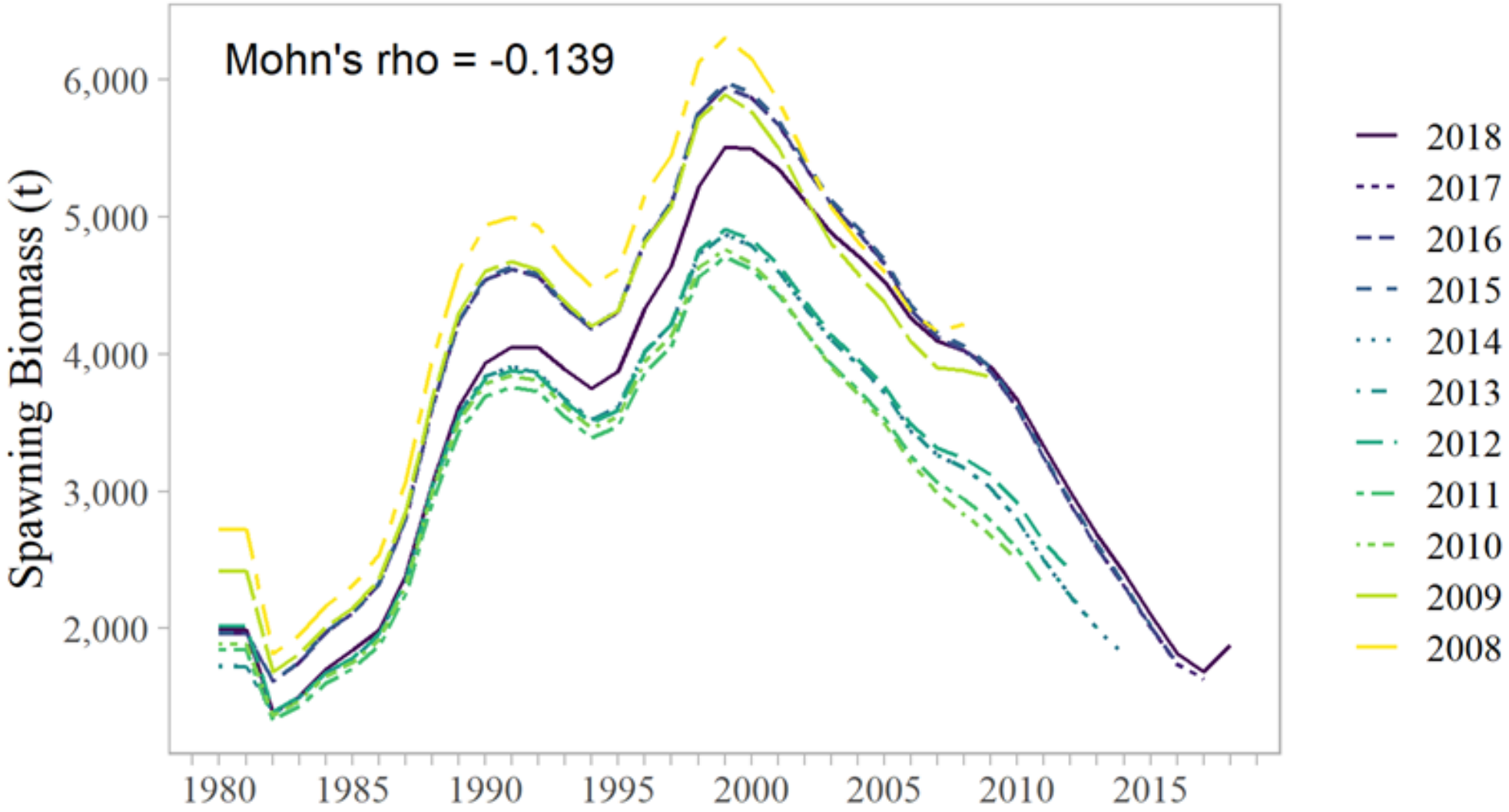

Mohn's rho = -0.139
Spawning Biomass (t)
6,000
5,000
4,000
3,000
2,000
1980
1985
1990
1995
2000
2005
2010
2015
2018
2017
2016
2015
2014
2013
2012
2011
2010
2009
2008

Figure 9-17

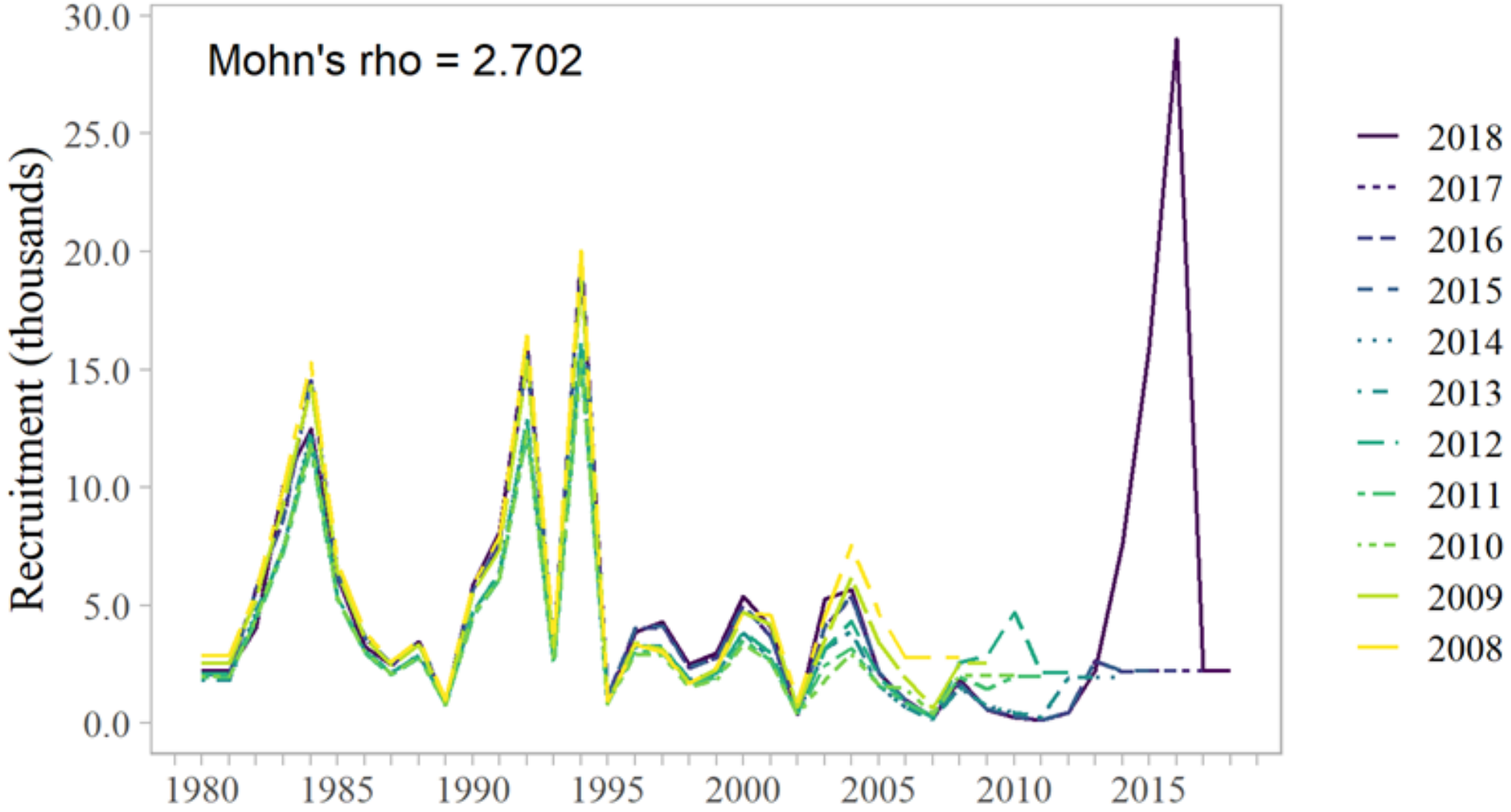
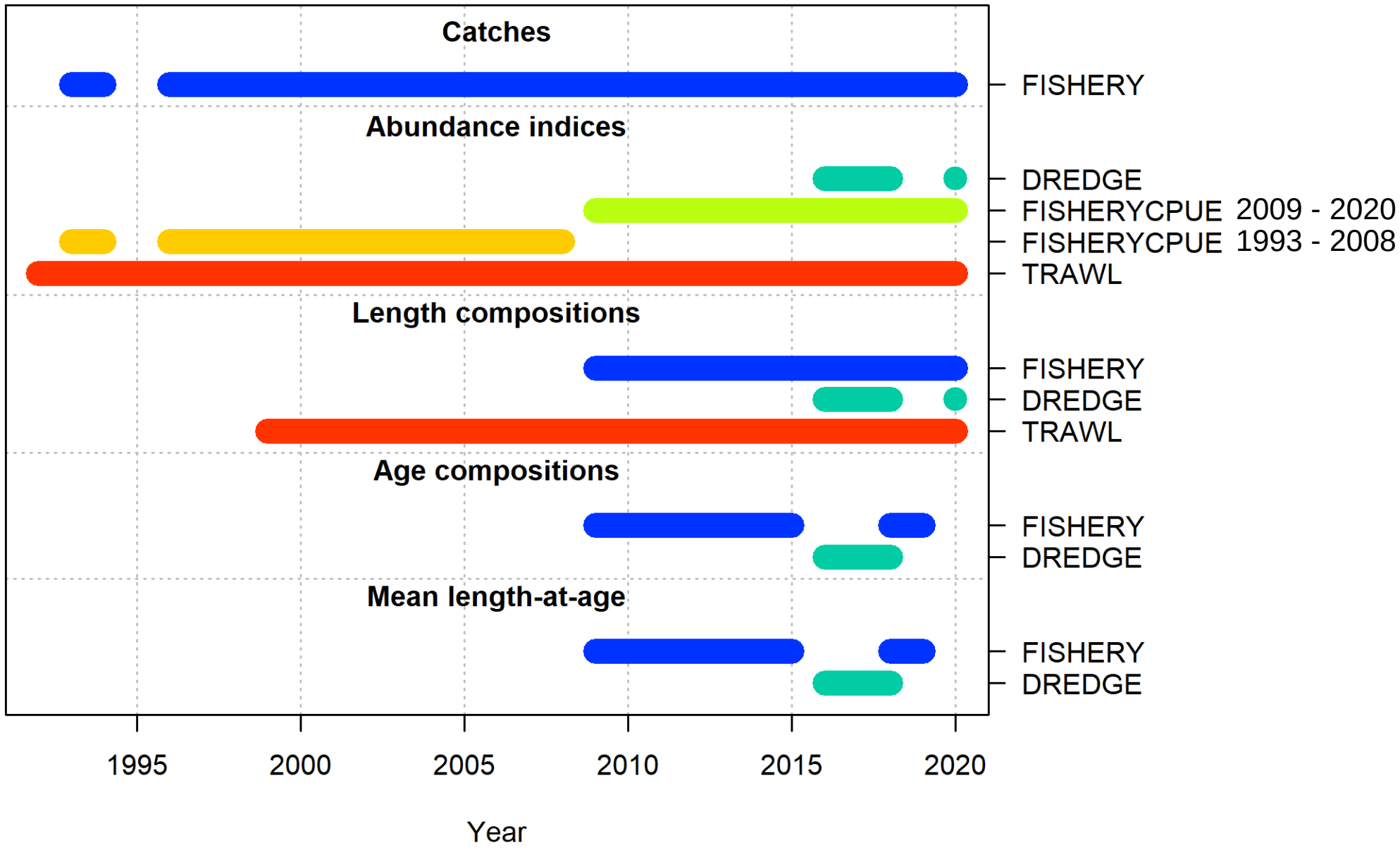
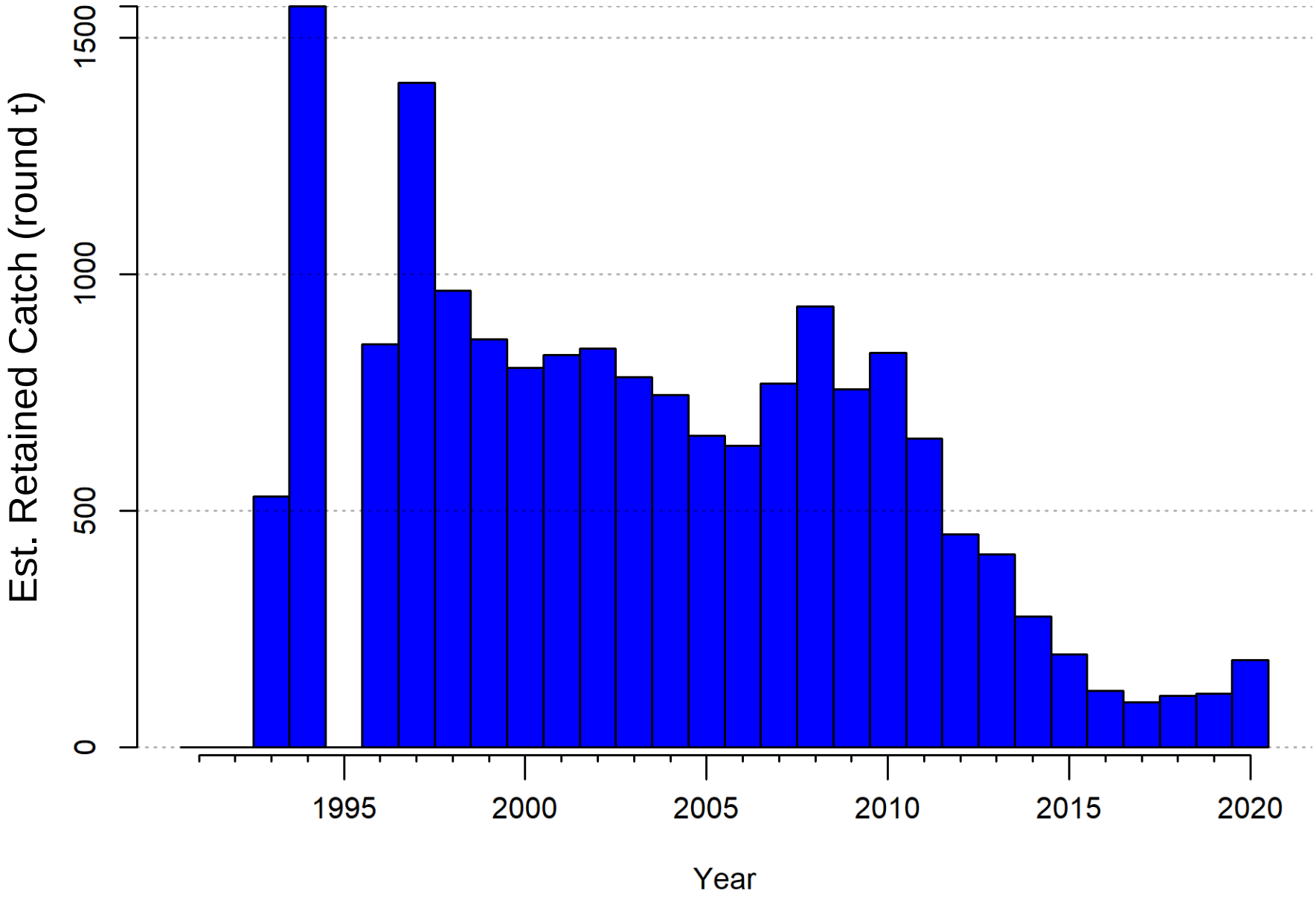

Mohn's rho = 2.702
Recruitment (thousands)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
2018
2017
2016
2015
2014
2013
2012
2011
2010
2009
2008

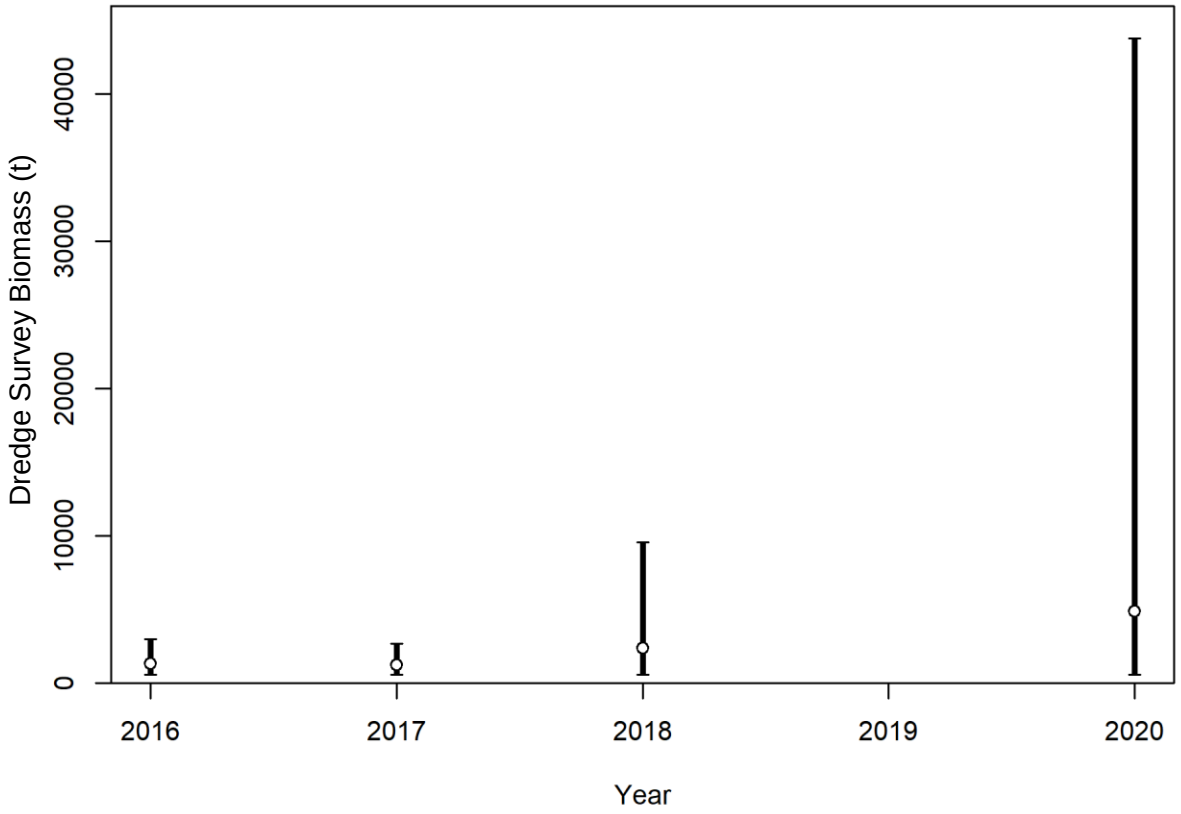
Figure 9-18

SHELIKOF

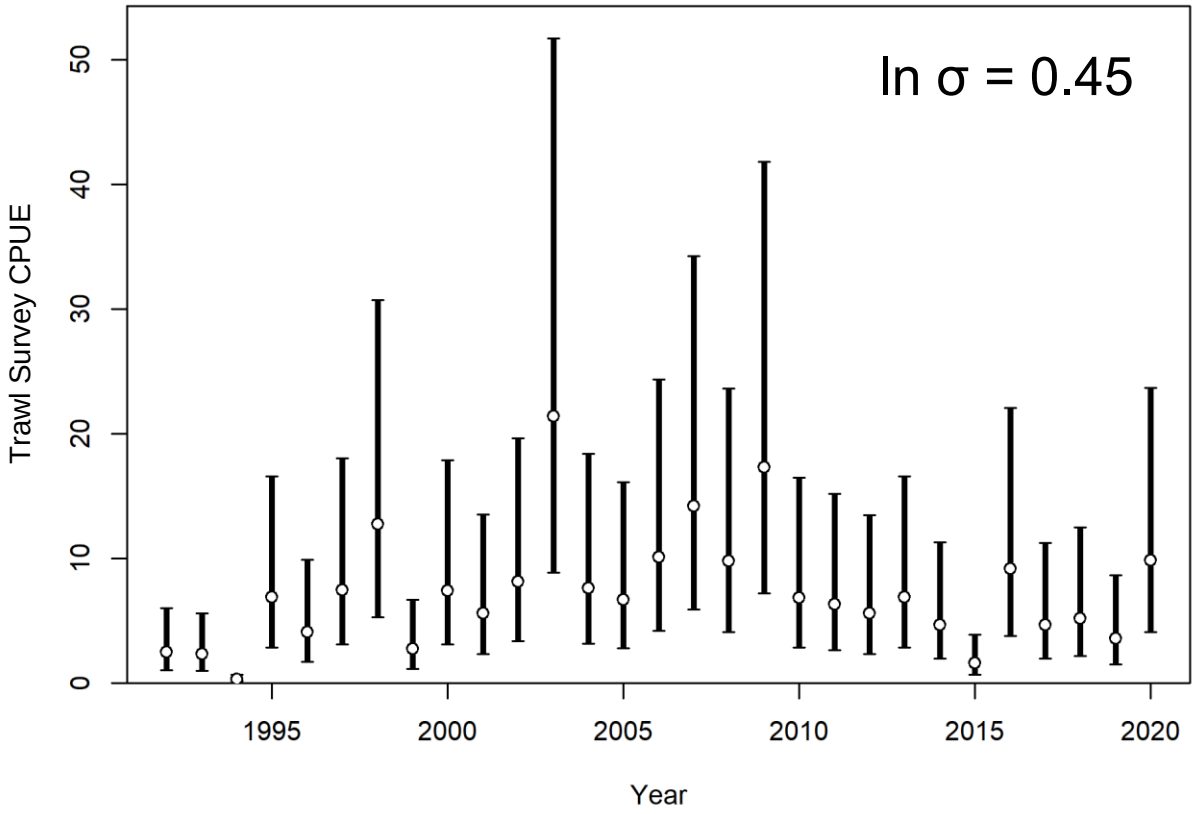

Catches
FISHERY
Abundance indices
DREDGE
FISHERYCPUE 2009 - 2020
FISHERYCPUE 1993 - 2008
TRAWL
Length compositions
FISHERY
DREDGE
TRAWL
Age compositions
FISHERY
DREDGE
Mean length-at-age
FISHERY
DREDGE
1995
2000
2005
2010
2015
2020
Year


Est. Retained Catch (round t)
0
500
1000
1500
1995
2000
2005
2010
2015
2020
Year

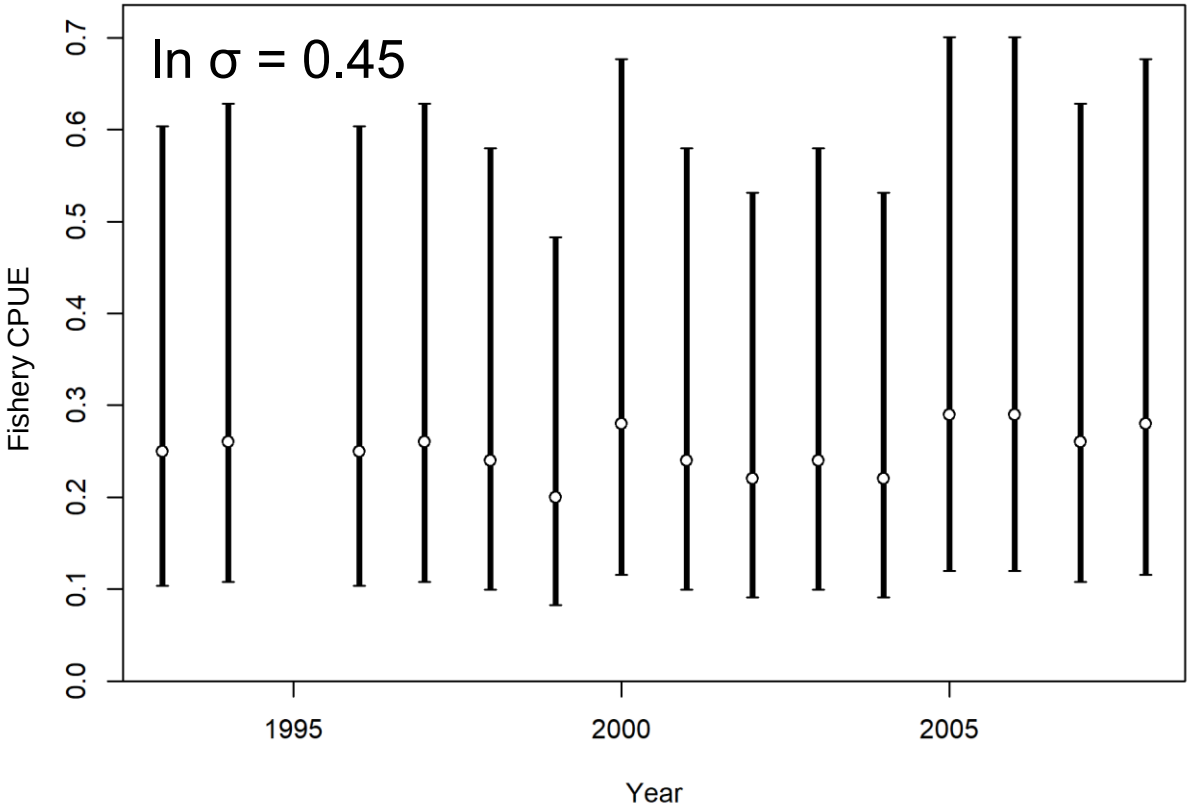
Dredge Survey Round Biomass



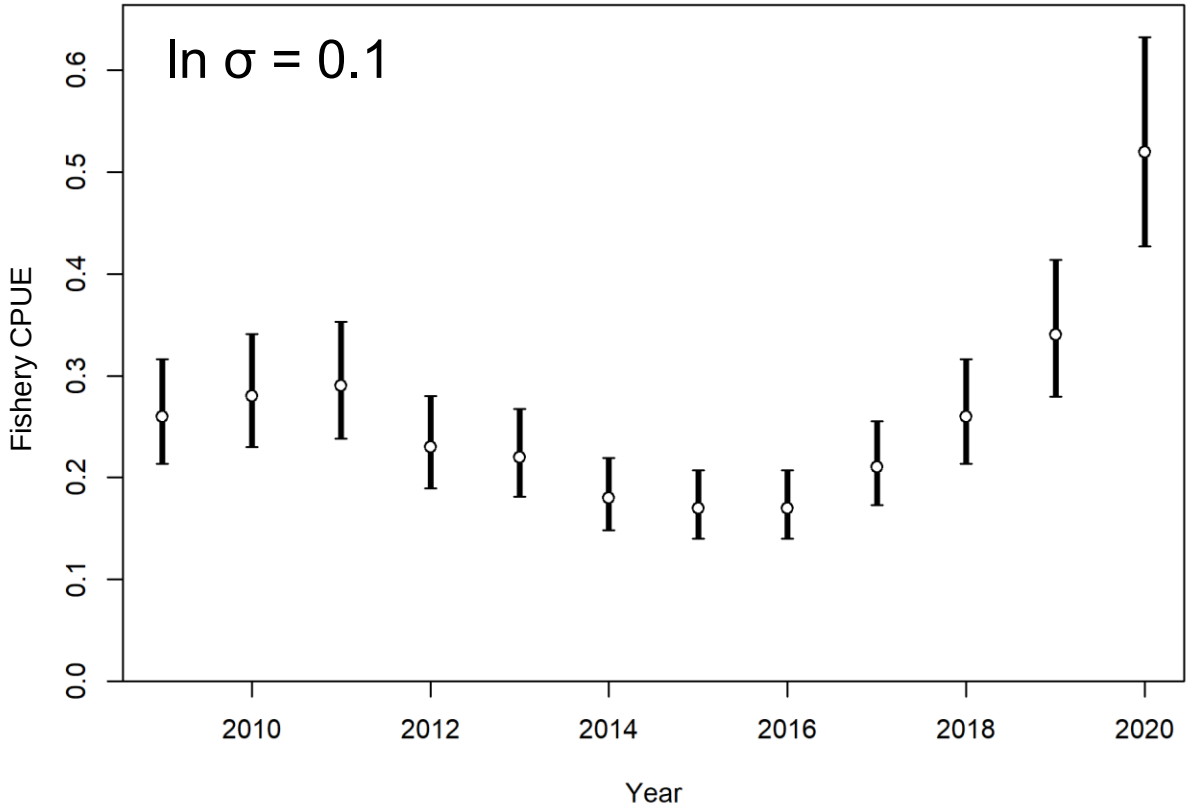
Trawl Survey CPUE

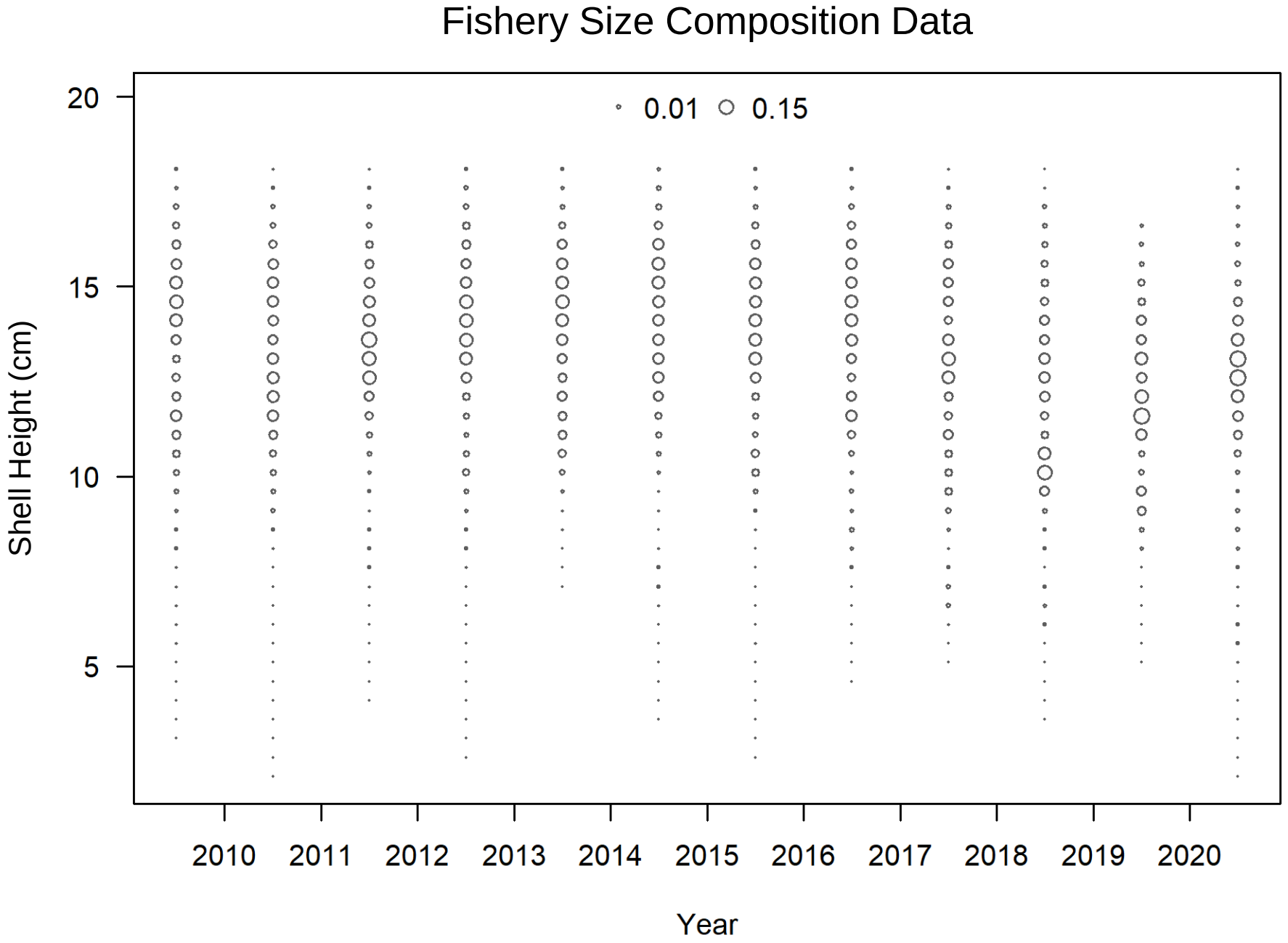


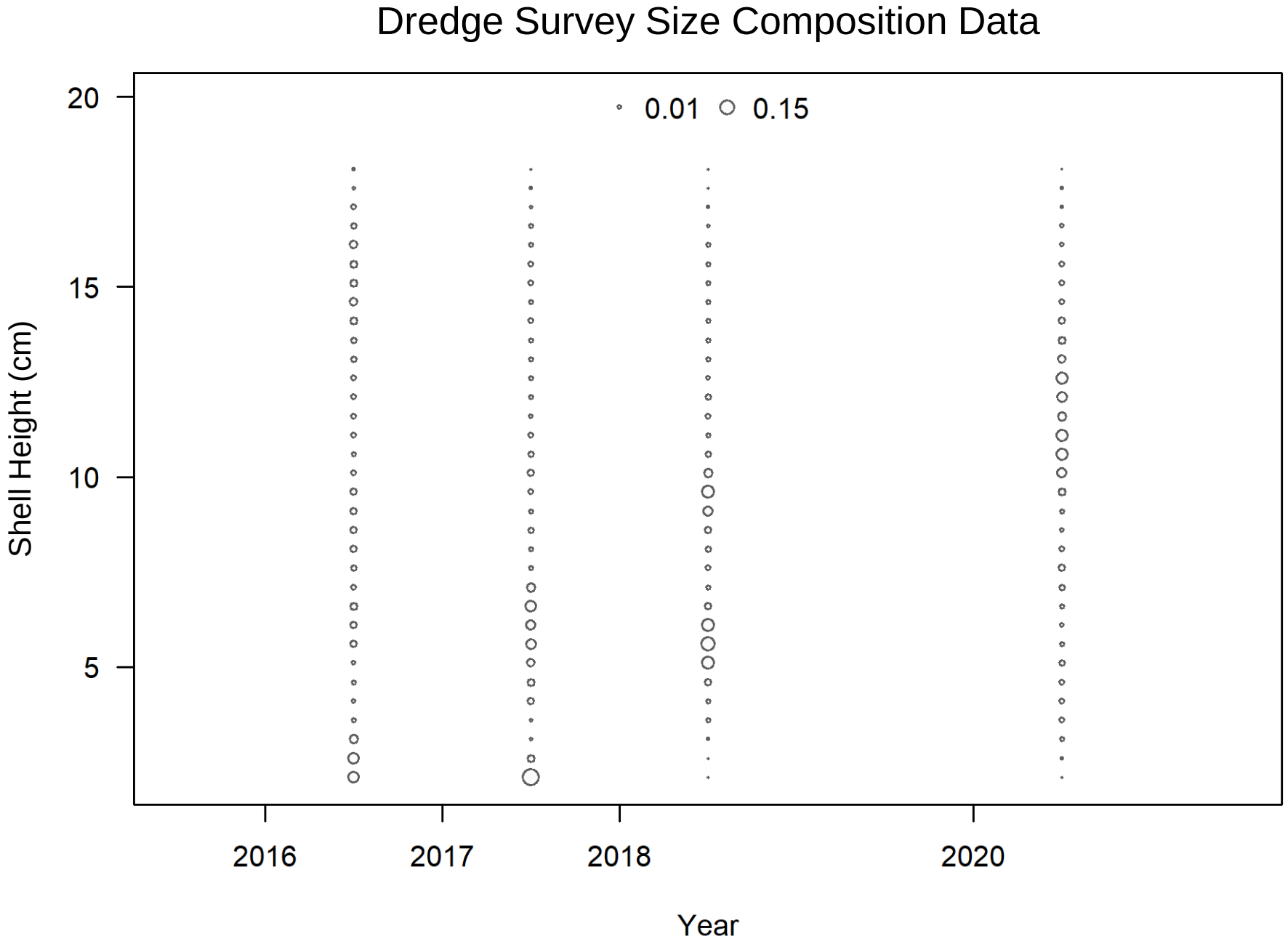
Fishery CPUE 1993 – 2008/09



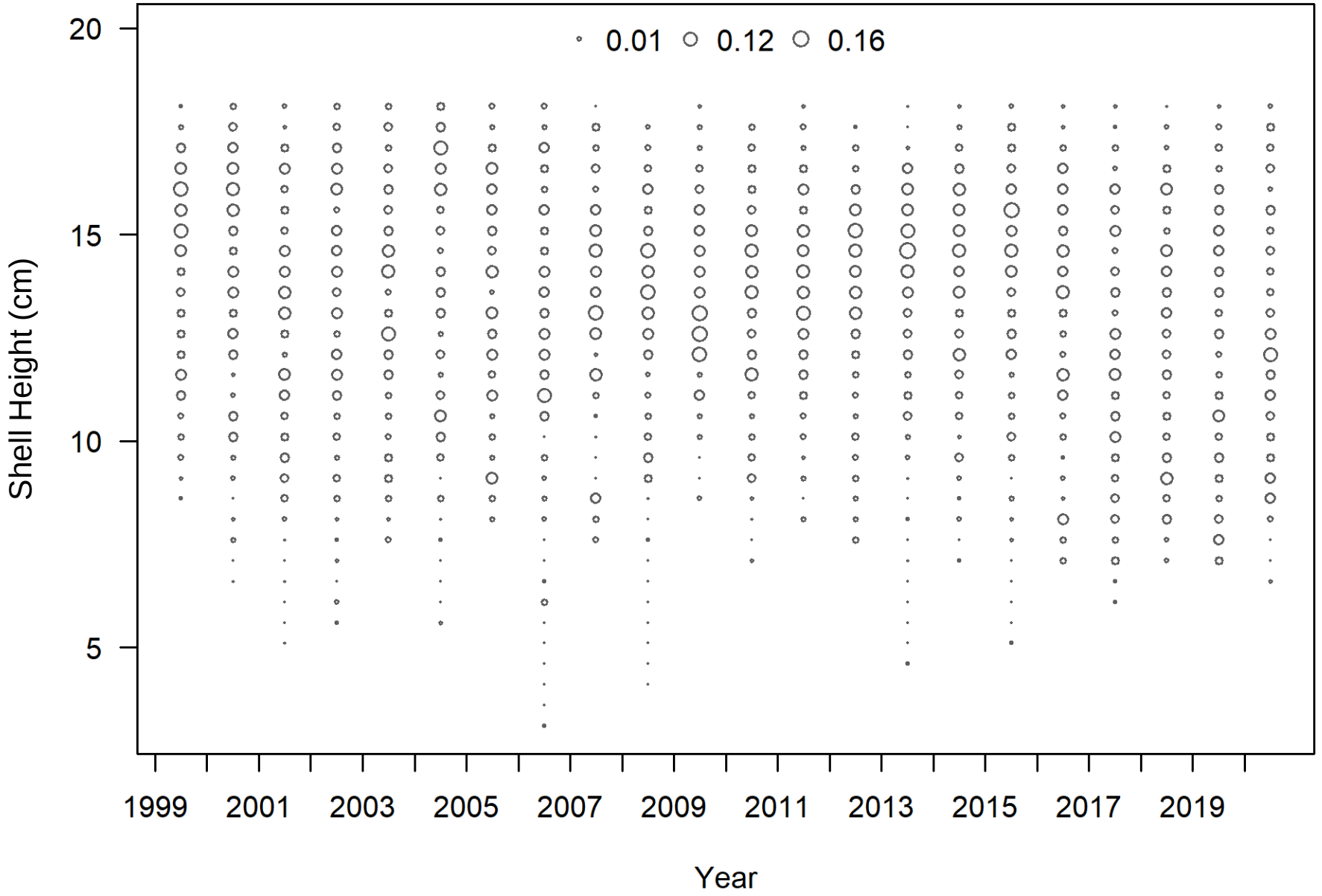
Fishery CPUE 2009/10 – 2020/21

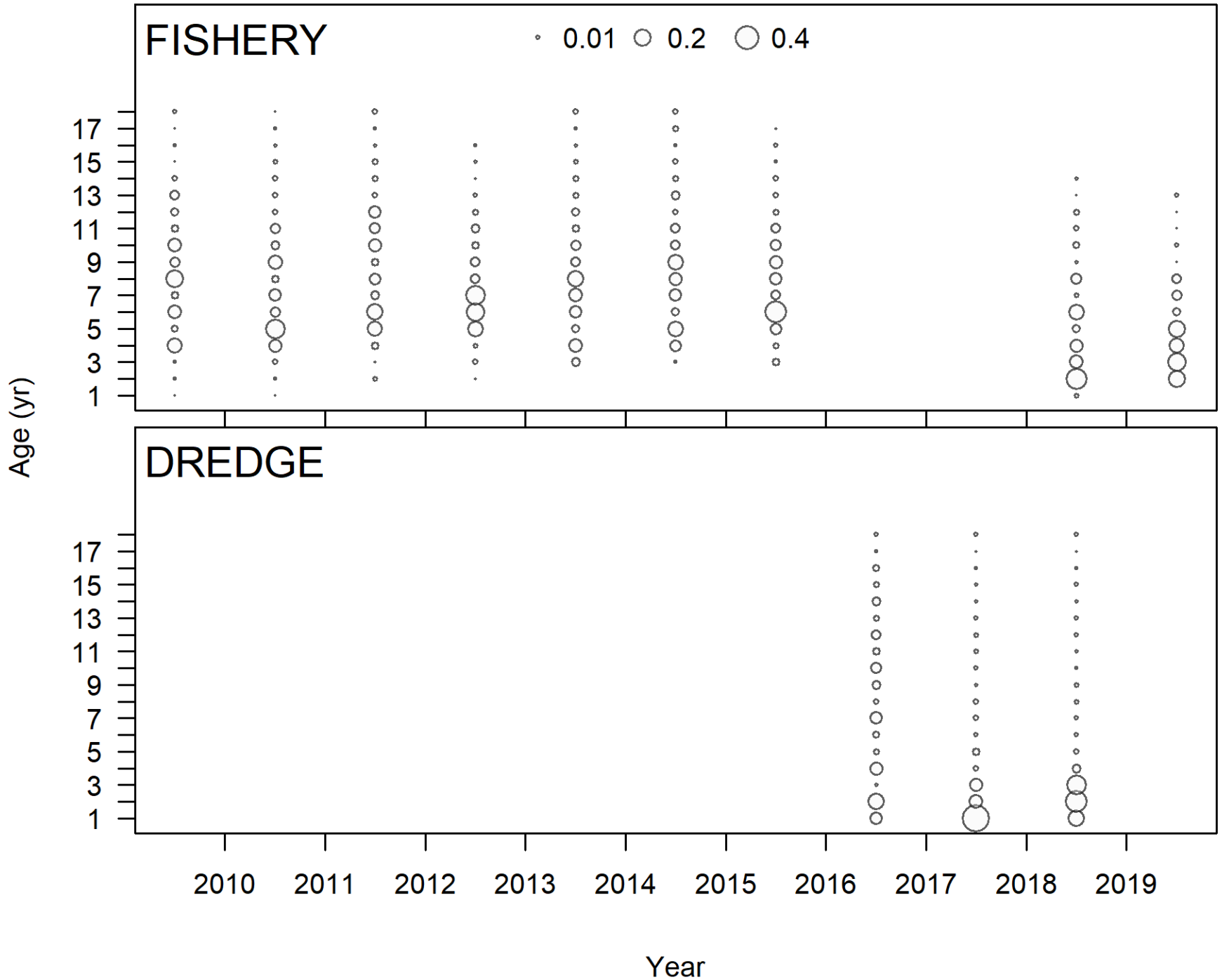



Fishery Size Composition Data
0.01
0.15
Shell Height (cm)
20
15
10
5
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Year


Dredge Survey Size Composition Data
0.01
0.15
20
15
10
5
Shell Height (cm)
2016
2017
2018
2020
Year

Trawl Survey Size Composition Data




FISHERY
0.01
0.2
0.4
DREDGE
Age (yr)
17
15
13
11
9
7
5
3
1
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

Kodiak Shelikof Model Scenarios

KSH 22.0: Base model

- Fishery catch from 1993 – 2020
- Fishery CPUE from 2009– 2020
- Dredge survey biomass from 2016 - 2020

KSH 22.1: Base model + Fishery CPUE data 1993 – 2008

KSH 22.1a: KSH 22.1 + M = 0.14 yr^{-1}

KSH 22.1b: KSH 22.1 + M = 0.24 yr^{-1}

KSH 22.2: KSH 22.1 with trawl survey data from 1992 - 2020

Table 9-9. Number of free parameters by model process for each Kodiak Shelikof District model.

	Models				
	KSH 22.0	KSH 22.1	KSH 22.1a	KSH 22.1b	KSH 22.2
Total	58	59	59	59	62
Growth	5	5	5	5	5
Virgin Recruitment	1	1	1	1	1
Recruitment Deviations	47	47	47	47	47
Catchability	1	2	2	2	3
Size Selectivity	4	4	4	4	6

Table 9-10. Negative log likelihood components for Kodiak Shelikof District models.

	Models				
Likelihood Component	KSH 22.0	KSH 22.1	KSH 22.1a	KSH 22.1b	KSH 22.2
Total	314.274	304.553	314.602	295.704	541.505
Fishery Catch	4.56E-08	4.24E-06	4.51E-06	1.14E-06	1.14E-05
Dredge Survey Biomass	-0.598	-0.635	-0.093	-1.098	-1.848
Fishery CPUE (≤ 2008/09)		-11.263	-10.861	-11.425	-6.668
Fishery CPUE (≥ 2009/10)	-17.913	-18.021	-17.023	-18.692	-24.292
Trawl CPUE					11.006
Fishery SH Comp	147.045	147.227	149.697	144.916	120.734
Dredge Survey SH Comp	97.964	98.041	99.809	96.364	59.852
Trawl SH Comp					**250.233**
Fishery Age Comp	38.635	38.296	38.688	37.864	44.552
Dredge Survey Age Comp	29.126	29.067	28.792	29.365	29.611
Fishery Size-at-Age	10.871	11.083	12.948	9.214	40.641
Dredge Survey Size-at-Age	1.817	1.790	2.810	0.693	4.191
Parameter Priors	0.944	1.658	1.662	1.654	2.445

Table 9-11. Parameter estimates for each Kodiak Shelikof District model.

	Models					
	KSH_22.0	KSH_22.1	KSH_22.1a	KSH_22.1b	KSH_22.2	Bounds
Natural Mortality*	0.19	0.19	0.14	0.24	0.19	
Weight-at-SH α*	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	
Weight-at-SH β*	2.786	2.786	2.786	2.786	2.786	
Size at 50% maturity*	7.3	7.3	7.3	7.3	7.3	
Maturity slope*	-1.5	-1.5	-1.5	-1.5	-1.5	
Log Virgin Rec	9.291	9.076	8.492	9.627	8.561	(1, 25)
SD Log Rec*	2	2	2	2	2	
LvB Growth Min SH	2.293	2.291	2.283	2.300	2.166	(-1, 8)
LvB Growth Max SH	17.080	17.079	17.067	17.086	16.831	(15, 20)
LvB *k*	0.136	0.137	0.144	0.129	0.190	(0.05, 0.35)
CV growth < min SH	0.298	0.297	0.289	0.306	0.197	(0.05, 0.5)
CV growth > max SH	0.083	0.083	0.082	0.085	0.078	(0.01, 0.25)
Fishery (≤ 2008/09) ln Q		-8.826	-8.809	-8.871	-9.022	(-12, 5)
Fishery (≥ 2009/10) ln Q	-8.342	-8.350	-8.270	-8.436	-8.730	(-12, 5)
Trawl Survey ln Q					-5.378	(-12, 5)
Fishery Size Sel p1	13.113	13.103	12.969	13.233	12.845	(2, 20)
Fishery Size Sel p2	3.312	3.314	3.385	3.241	3.363	(0.01, 8)
Dredge Survey Size Sel p1	13.137	13.125	12.798	13.405	12.355	(0.01, 45)
Dredge Survey Size Sel p2	6.976	7.001	7.477	6.568	8.417	(0.01, 20)
Trawl Survey Size Sel p1					13.378	(2, 20)
Trawl Survey Size Sel p2					4.276	(0.01, 8)

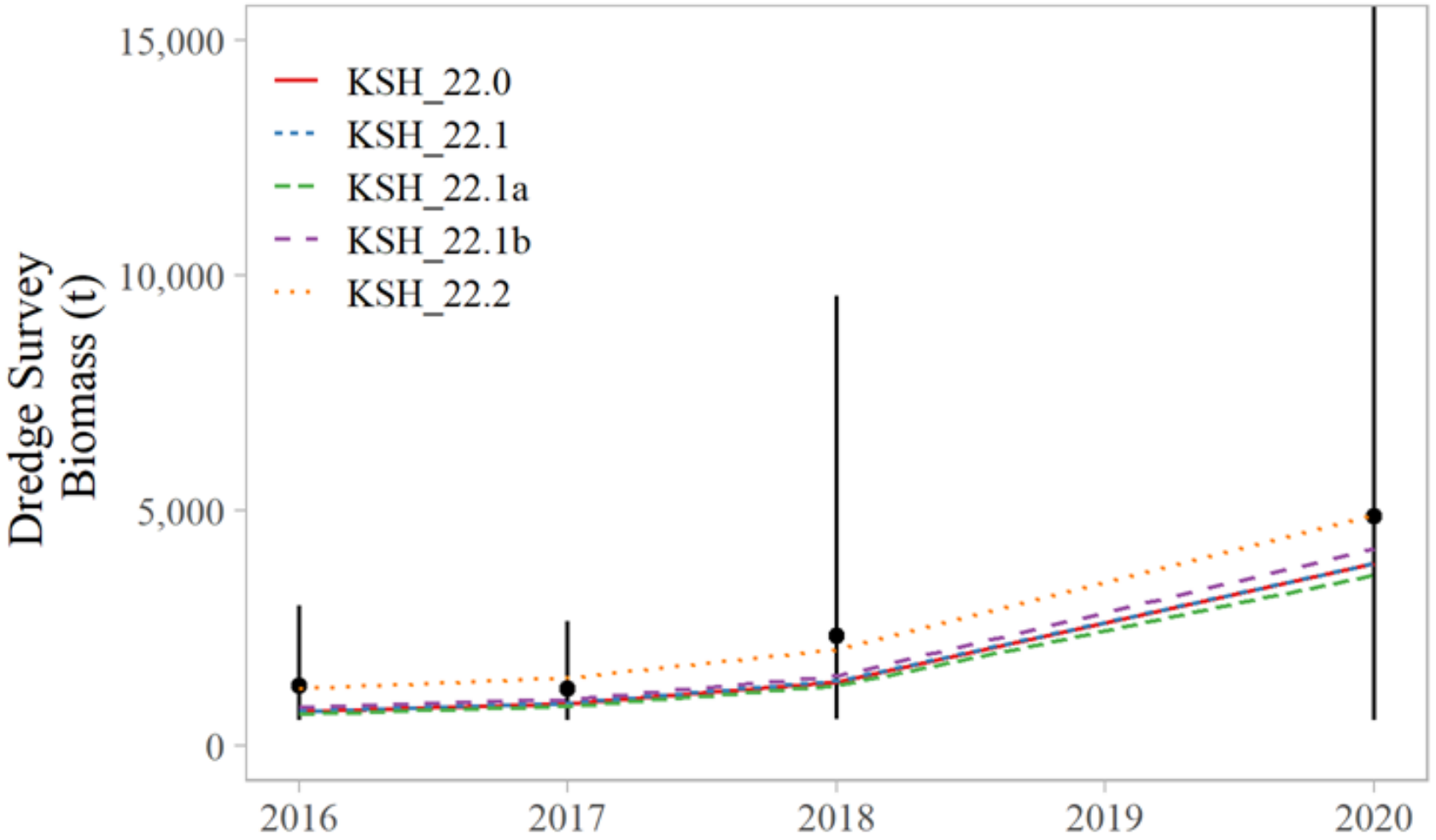

15,000
10,000
5,000
0
Dredge Survey
Biomass (t)
KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2
2016
2017
2018
2019
2020

Figure 9-19

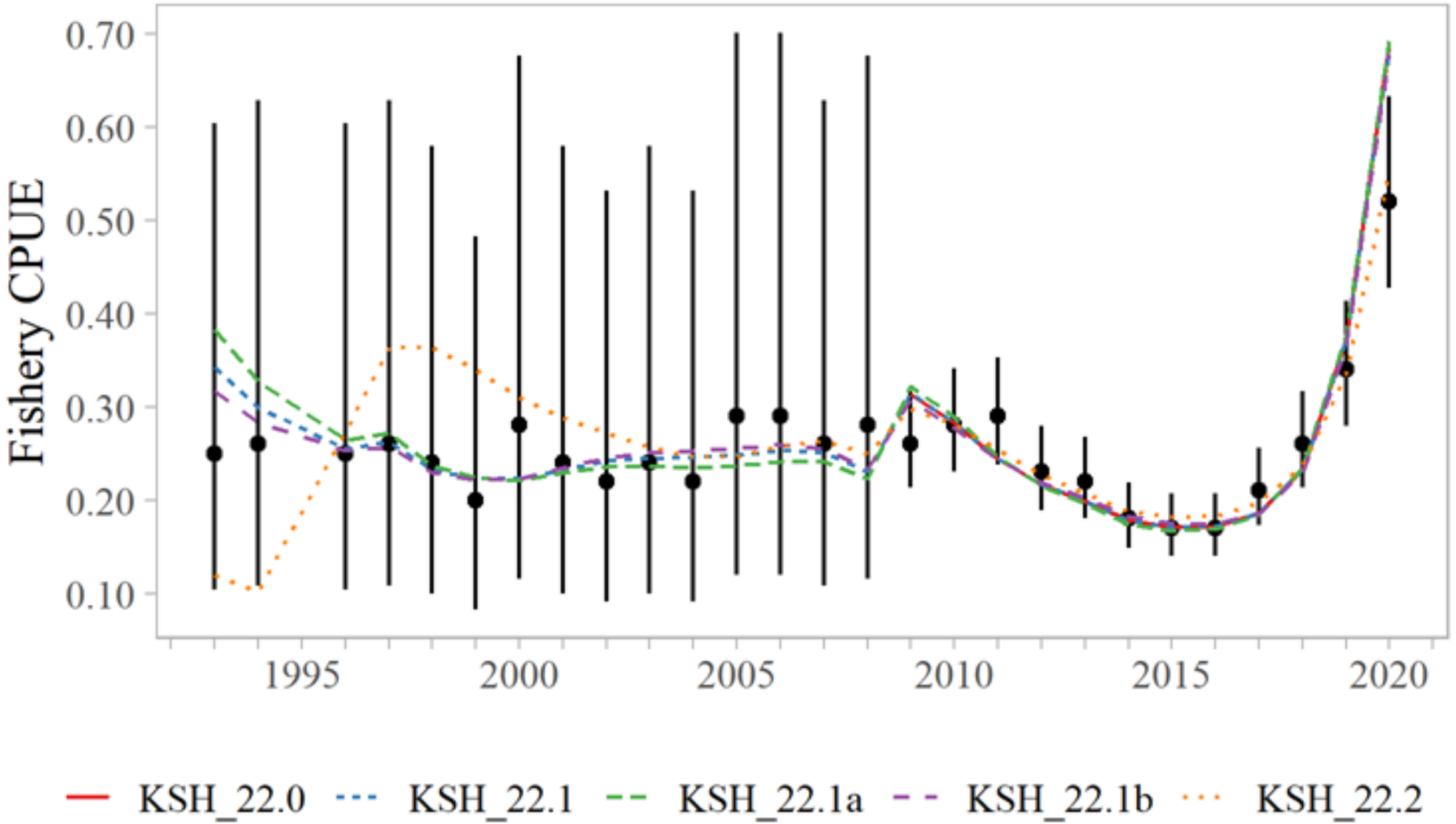

Fishery CPUE
0.70
0.60
0.50
0.40
0.30
0.20
0.10
1995
2000
2005
2010
2015
2020
KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2

Figure 9-20

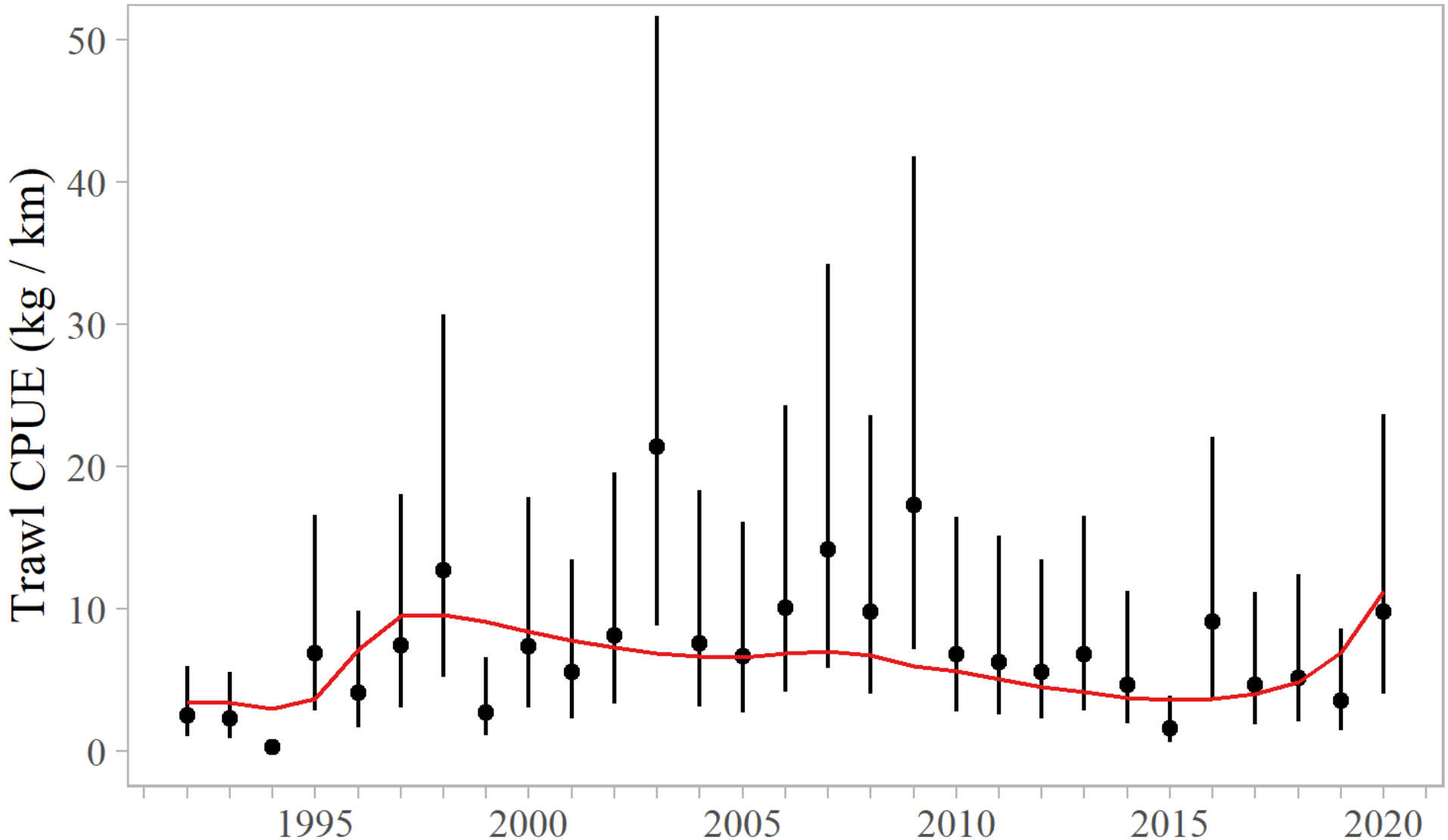


Figure 9-21

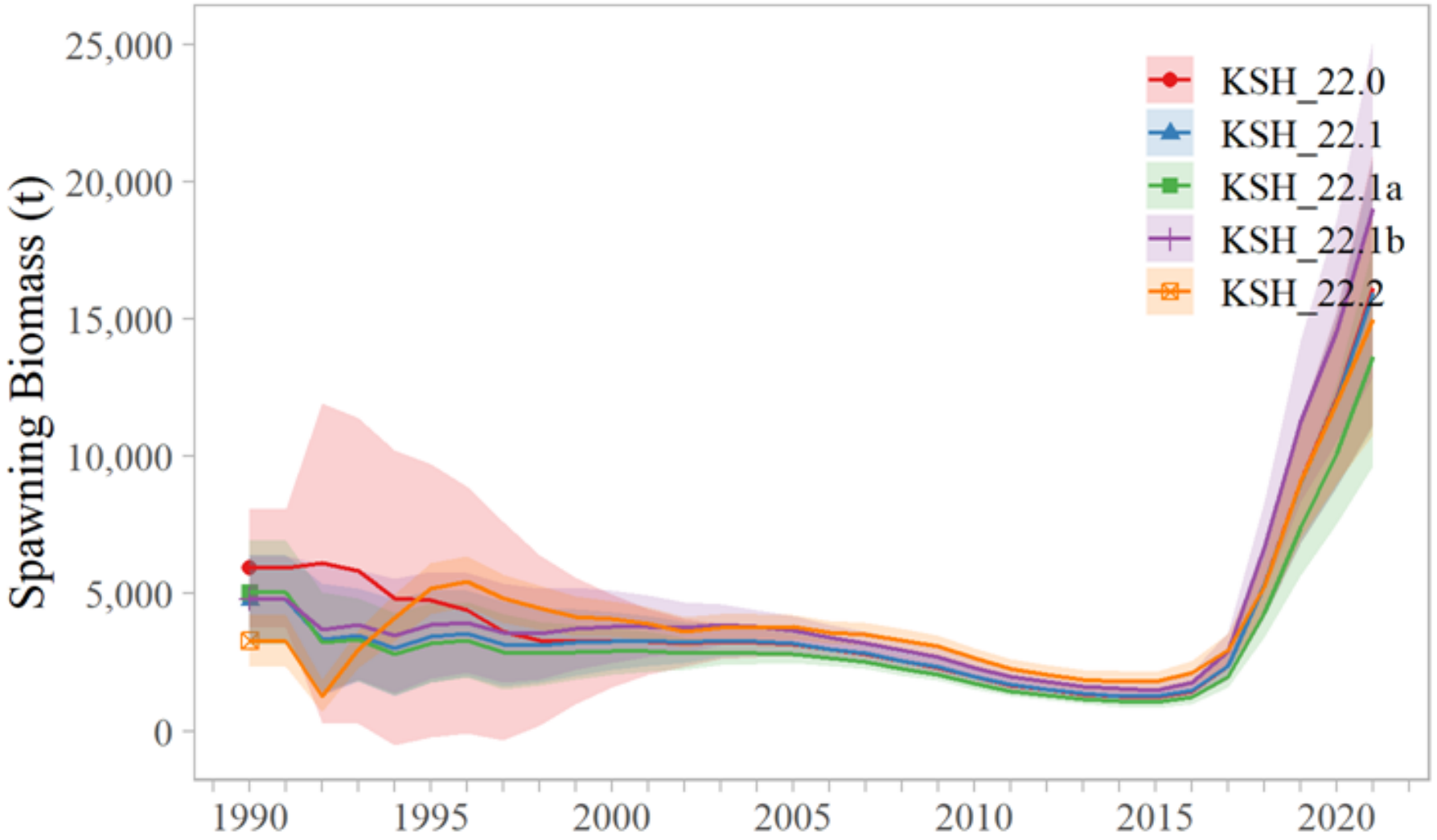

Spawning Biomass (t)
25,000
20,000
15,000
10,000
5,000
0
1990
1995
2000
2005
2010
2015
2020
KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2

Figure 9-22.

	Models				
	KSH_22.0	KSH_22.1	KSH_22.1a	KSH_22.1b	KSH_22.2
Log Virgin Rec	9.291	9.076	8.492	9.627	8.561
Unfished *R* (millions)	10.844	8.746	4.876	15.169	5.225

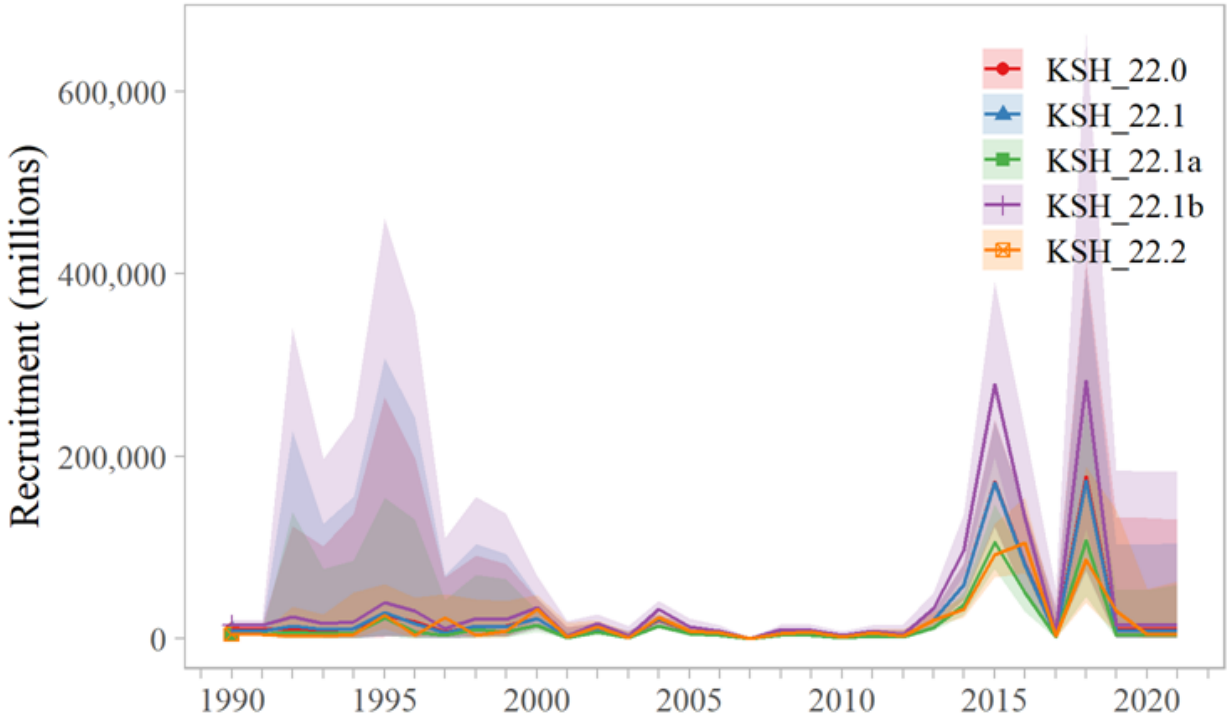


Figure 9-23

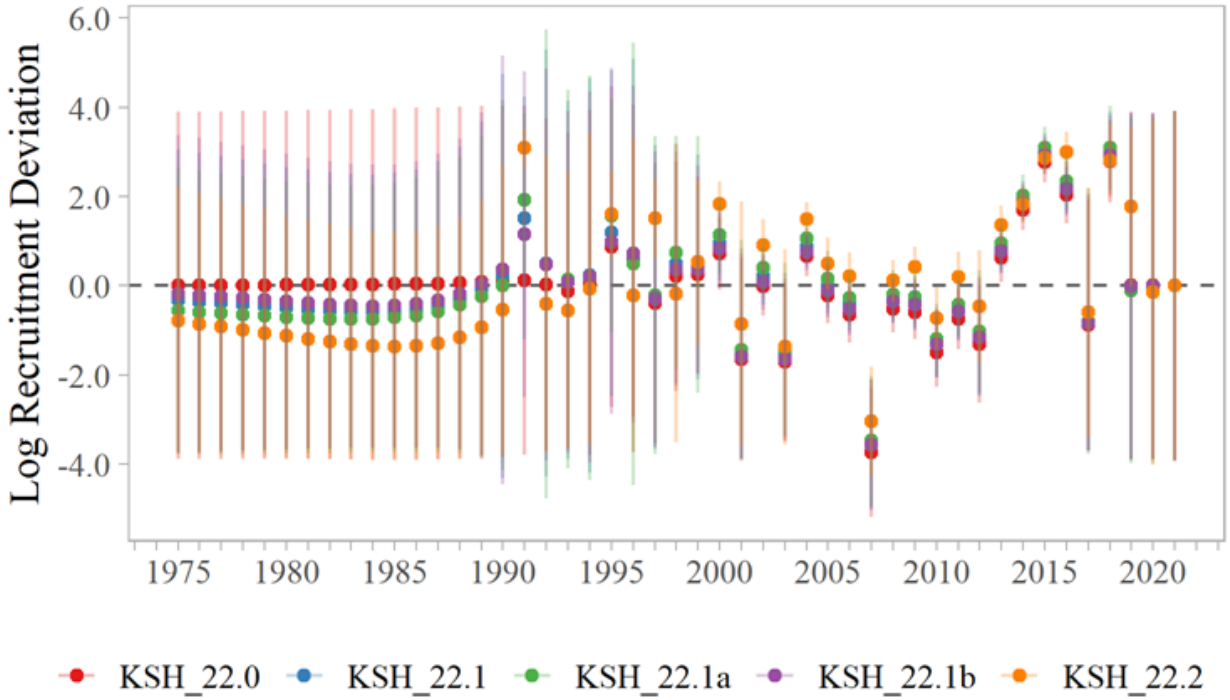
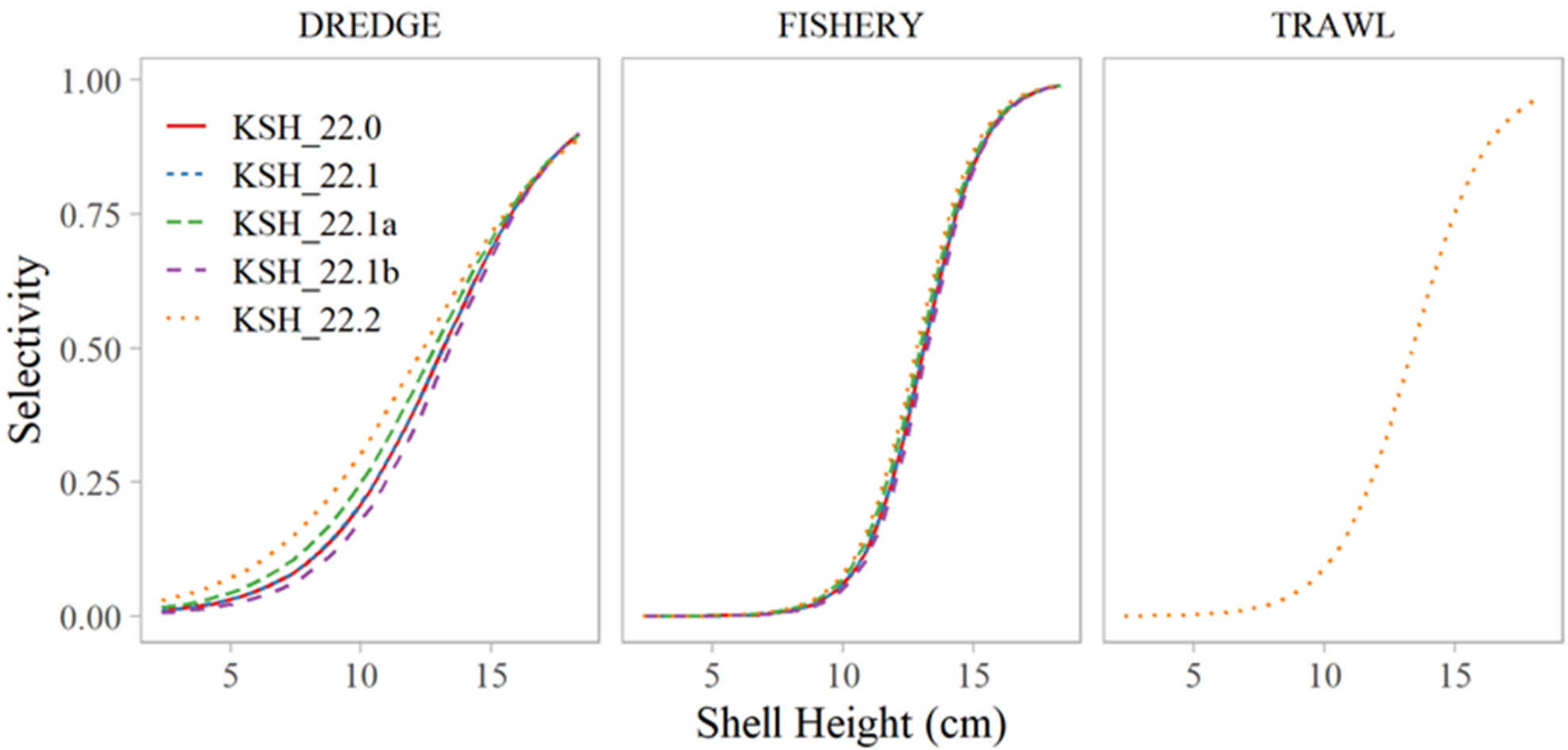


Figure 9-24


DREDGE
FISHERY
TRAWL
1.00
0.75
0.50
0.25
0.00
Selectivity
KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2
5
10
15
Shell Height (cm)

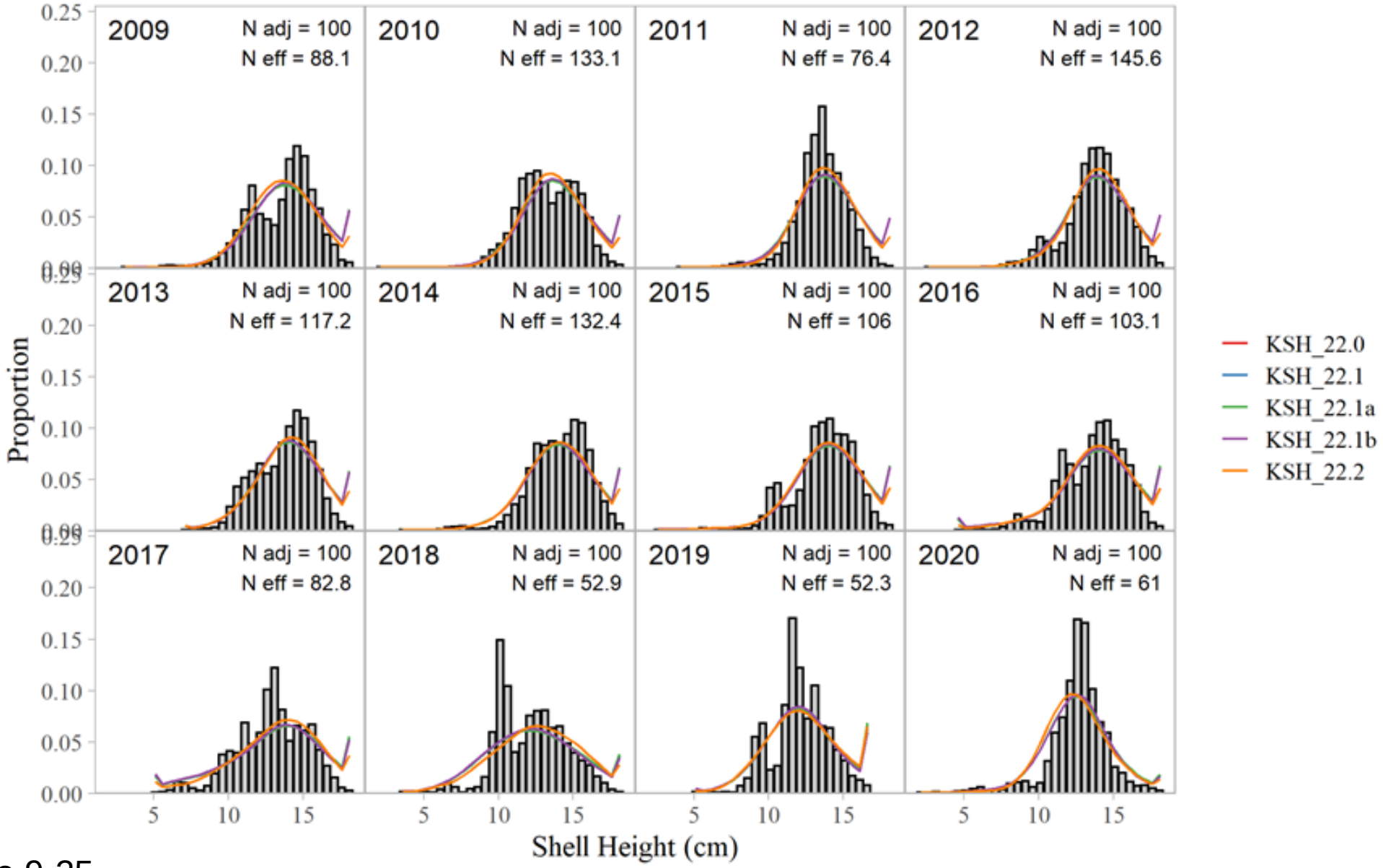
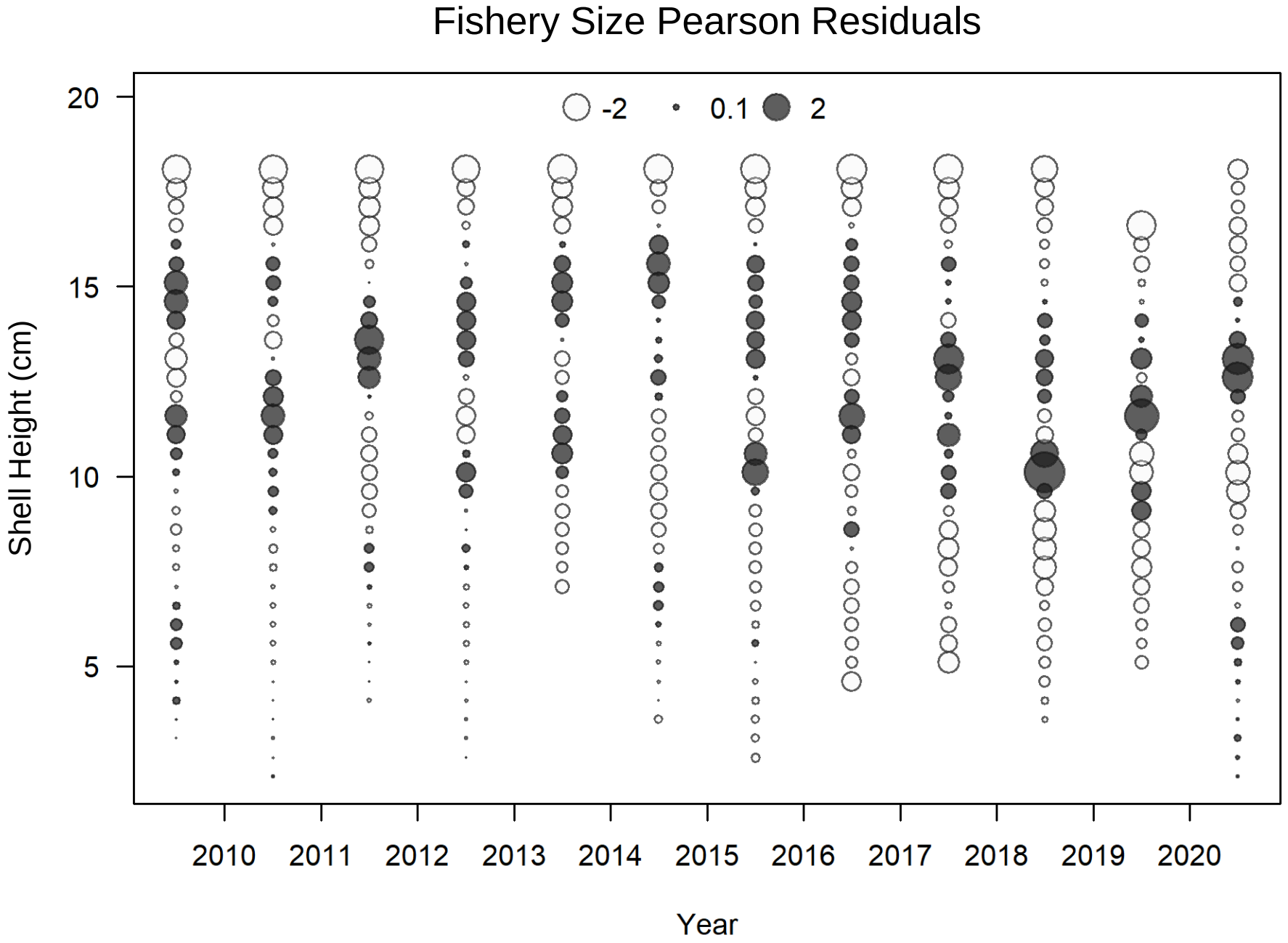

2009
N adj = 100
N eff = 88.1
2010
N adj = 100
N eff = 133.1
2011
N adj = 100
N eff = 76.4
2012
N adj = 100
N eff = 145.6
2013
N adj = 100
N eff = 117.2
2014
N adj = 100
N eff = 132.4
2015
N adj = 100
N eff = 106
2016
N adj = 100
N eff = 103.1
2017
N adj = 100
N eff = 82.8
2018
N adj = 100
N eff = 52.9
2019
N adj = 100
N eff = 52.3
2020
N adj = 100
N eff = 61
Proportion
0.25
0.20
0.15
0.10
0.05
0.00
5
10
15
Shell Height (cm)
KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2

Figure 9-25


Fishery Size Pearson Residuals
-2
0.1
2
20
15
10
5
Shell Height (cm)
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Year

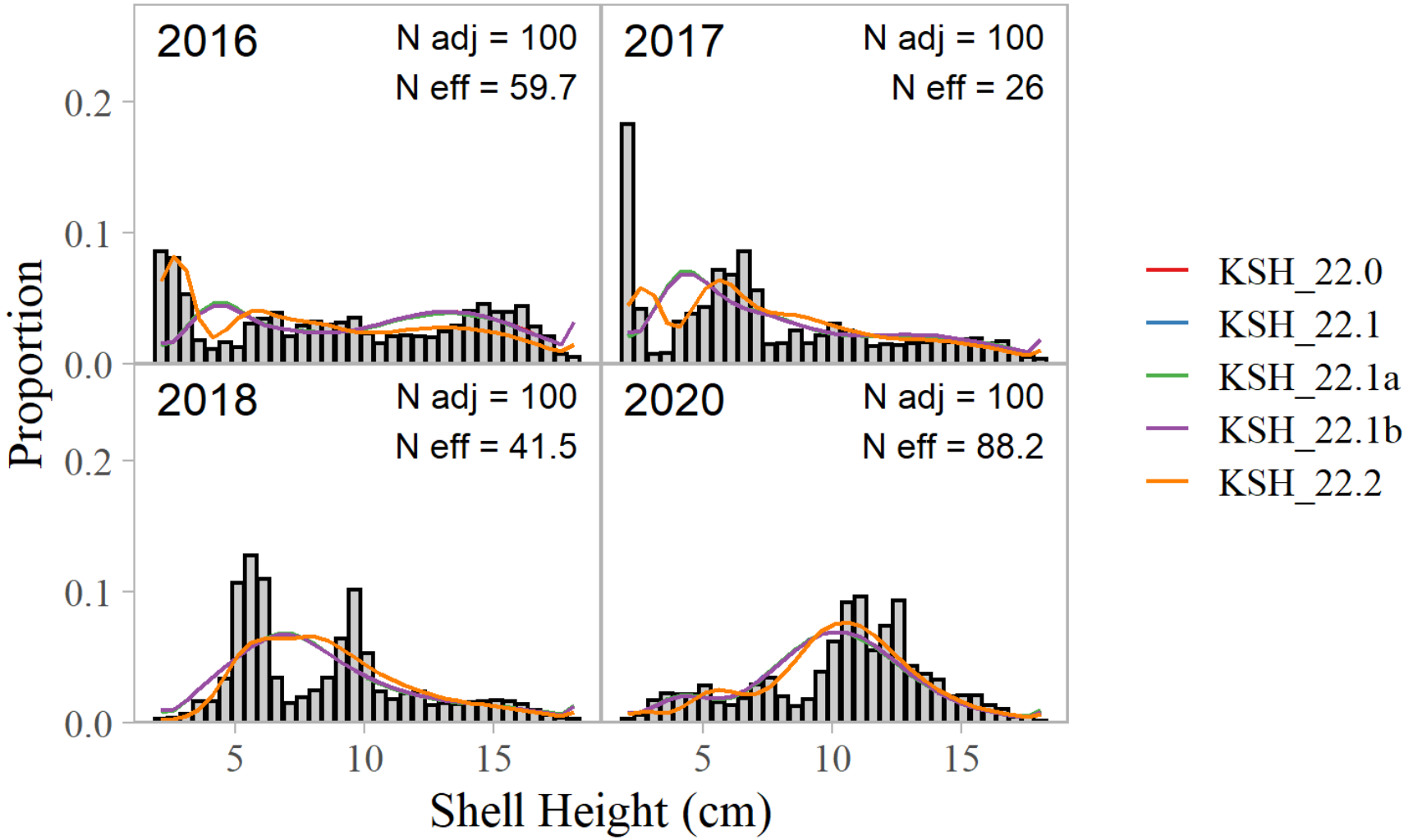
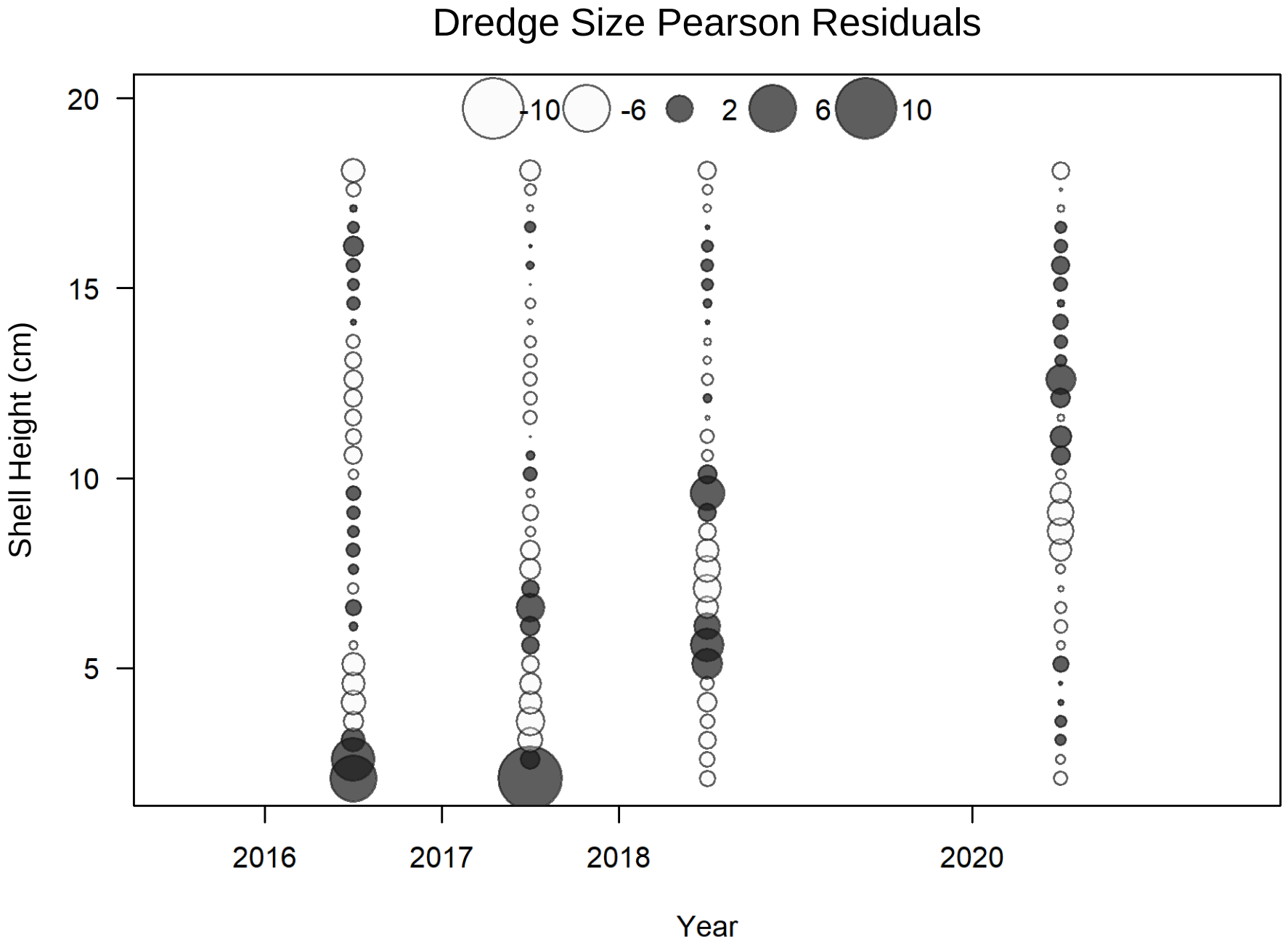

2016
N adj = 100
N eff = 59.7
2017
N adj = 100
N eff = 26
2018
N adj = 100
N eff = 41.5
2020
N adj = 100
N eff = 88.2
Proportion
0.0
0.1
0.2
5
10
15
Shell Height (cm)
KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2

Figure 9-26


Dredge Size Pearson Residuals
-10
-6
2
6
10
20
15
10
5
Shell Height (cm)
2016
2017
2018
2020
Year

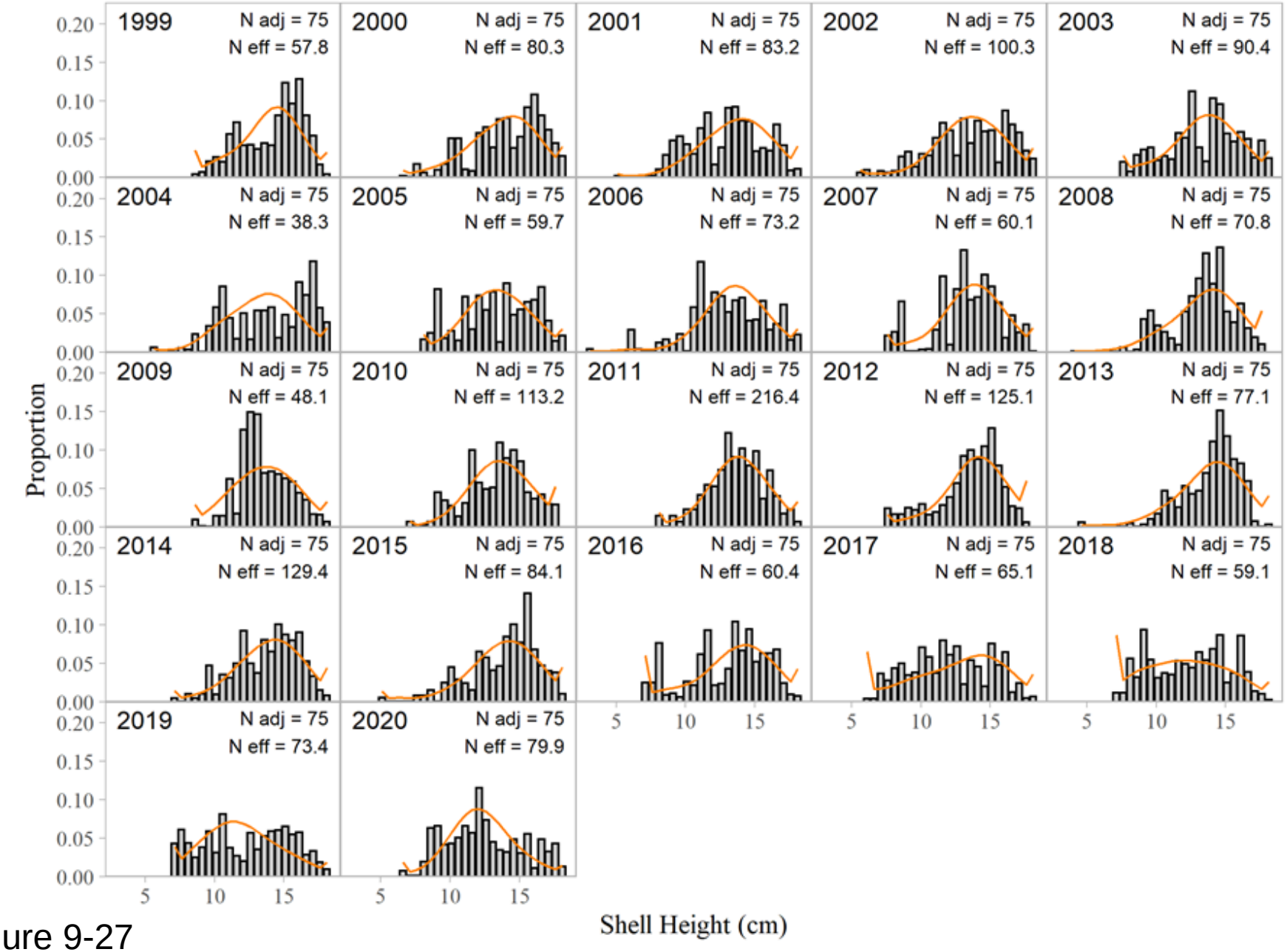
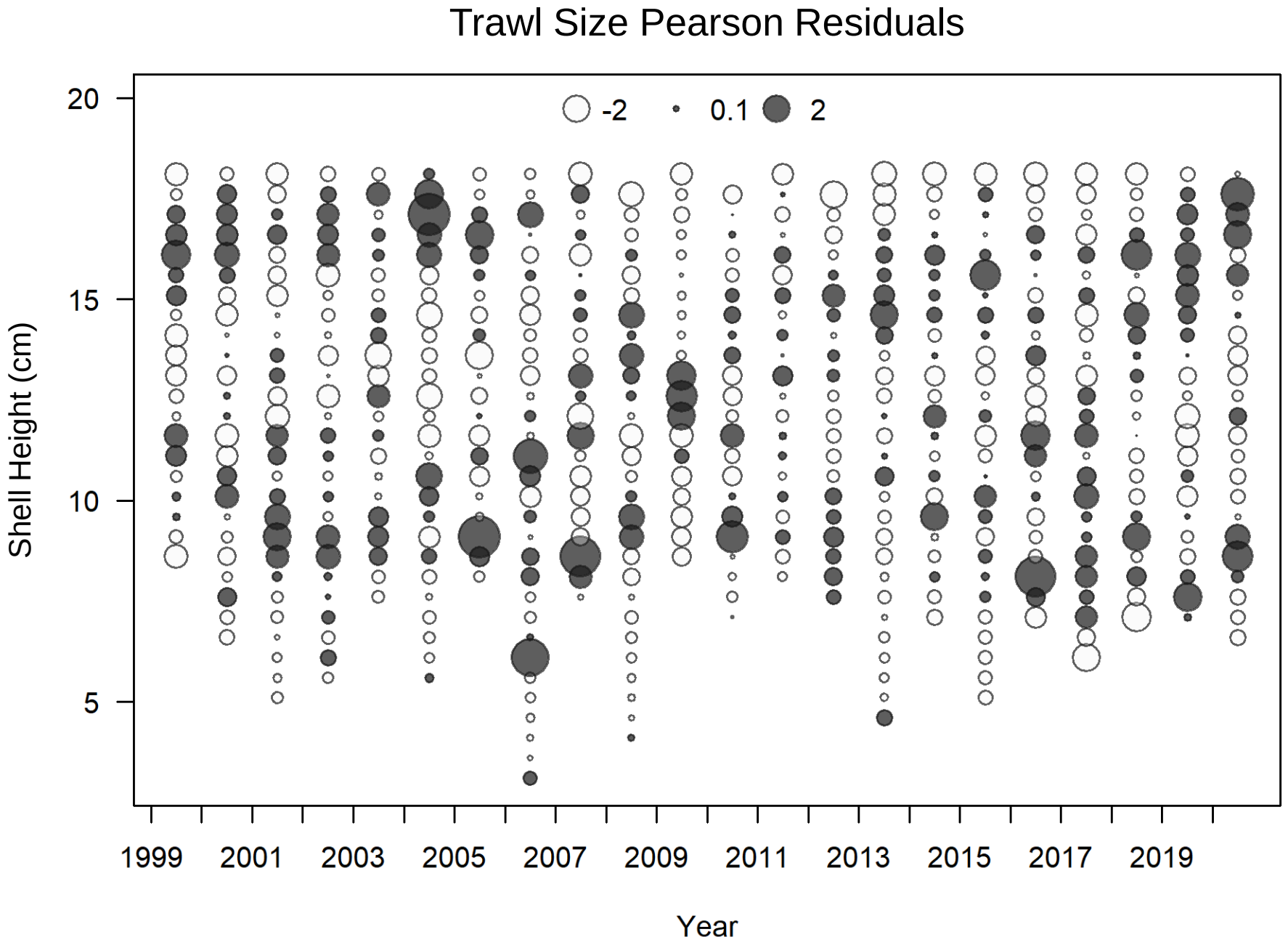

1999 N adj = 75 N eff = 57.8
2000 N adj = 75 N eff = 80.3
2001 N adj = 75 N eff = 83.2
2002 N adj = 75 N eff = 100.3
2003 N adj = 75 N eff = 90.4
2004 N adj = 75 N eff = 38.3
2005 N adj = 75 N eff = 59.7
2006 N adj = 75 N eff = 73.2
2007 N adj = 75 N eff = 60.1
2008 N adj = 75 N eff = 70.8
2009 N adj = 75 N eff = 48.1
2010 N adj = 75 N eff = 113.2
2011 N adj = 75 N eff = 216.4
2012 N adj = 75 N eff = 125.1
2013 N adj = 75 N eff = 77.1
2014 N adj = 75 N eff = 129.4
2015 N adj = 75 N eff = 84.1
2016 N adj = 75 N eff = 60.4
2017 N adj = 75 N eff = 65.1
2018 N adj = 75 N eff = 59.1
2019 N adj = 75 N eff = 73.4
2020 N adj = 75 N eff = 79.9
Proportion
0.00
0.05
0.10
0.15
0.20
5
10
15
Shell Height (cm)

Figure 9-27


Trawl Size Pearson Residuals
-2
0.1
2
20
15
10
5
Shell Height (cm)
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
Year

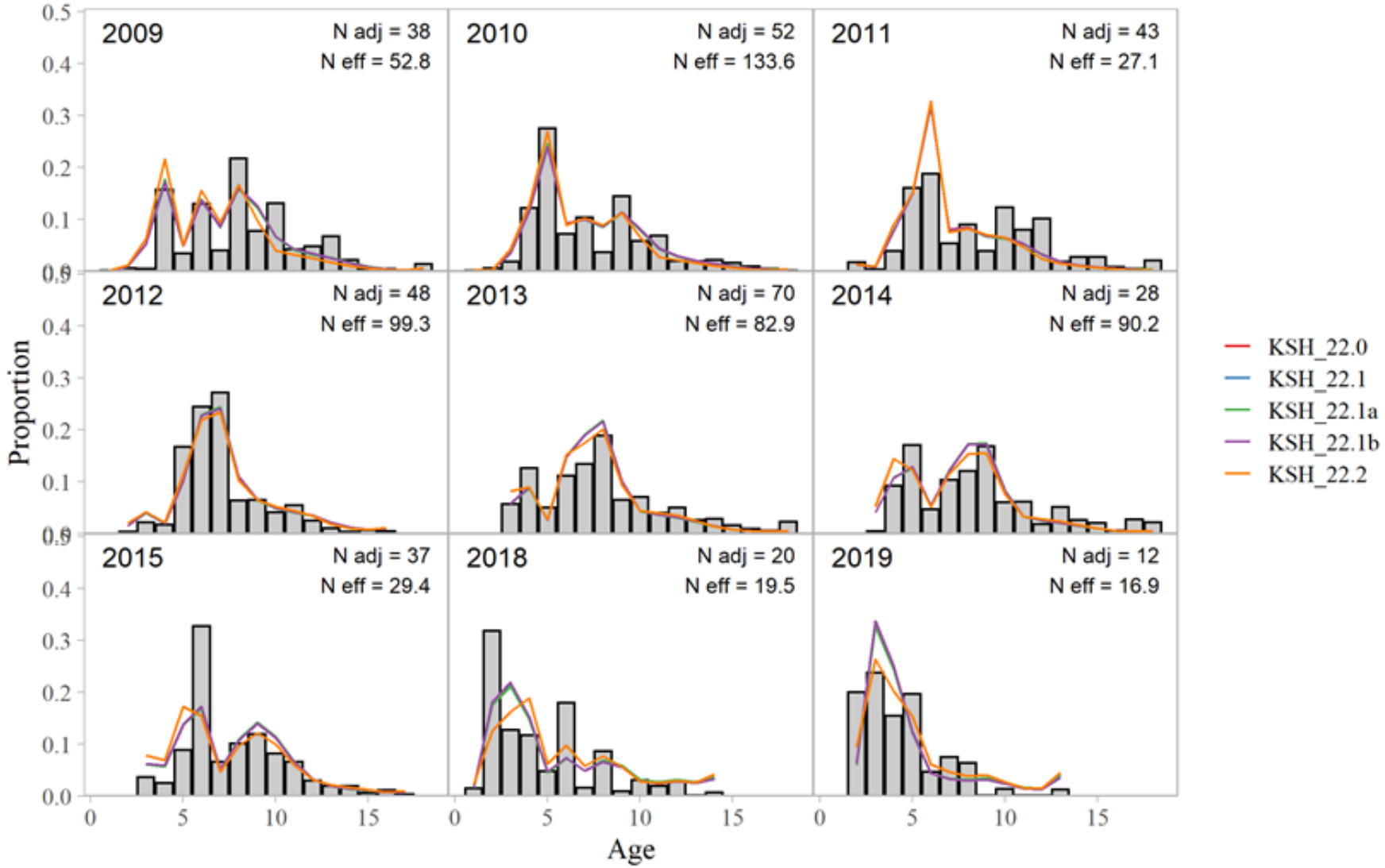
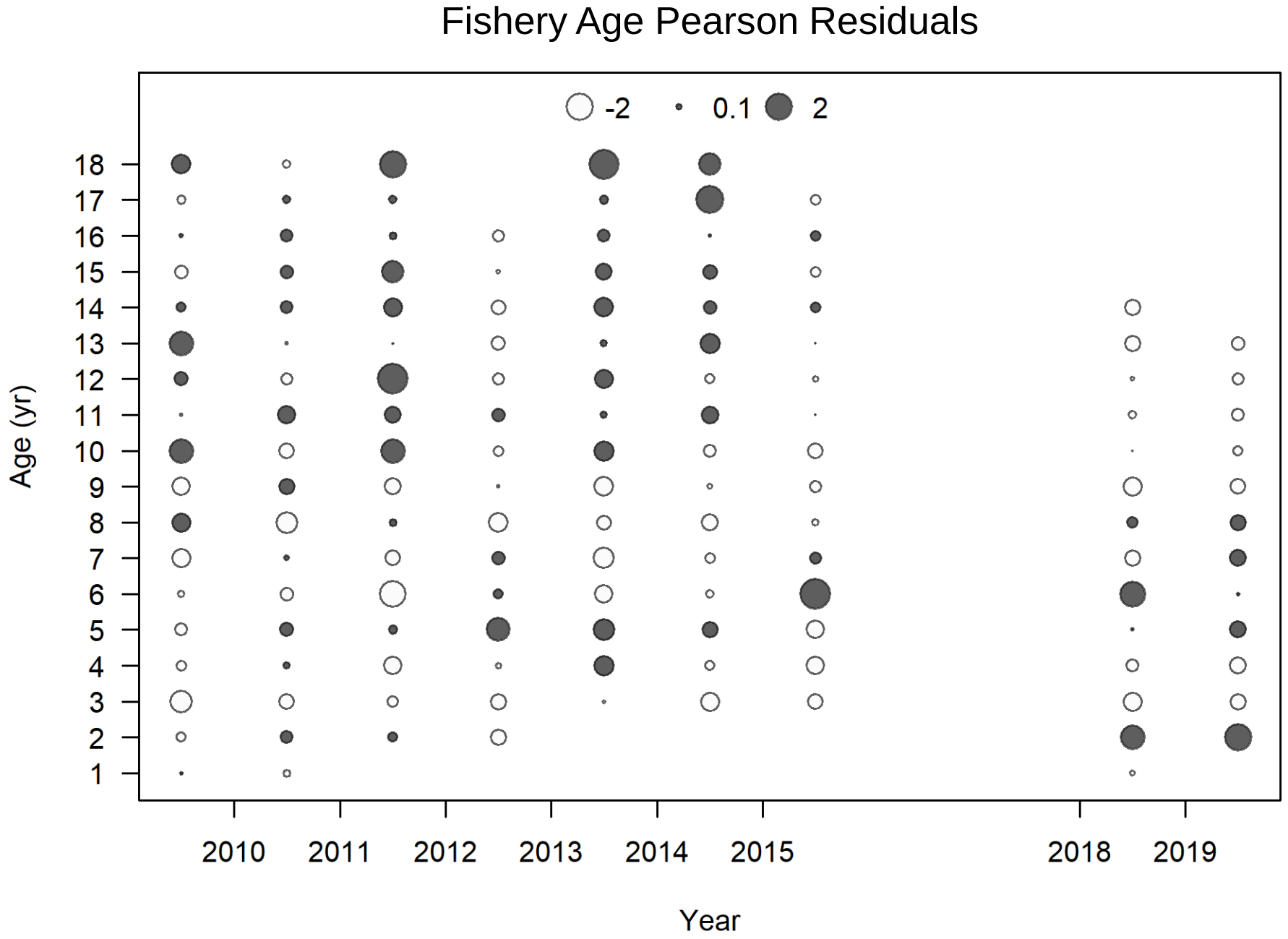
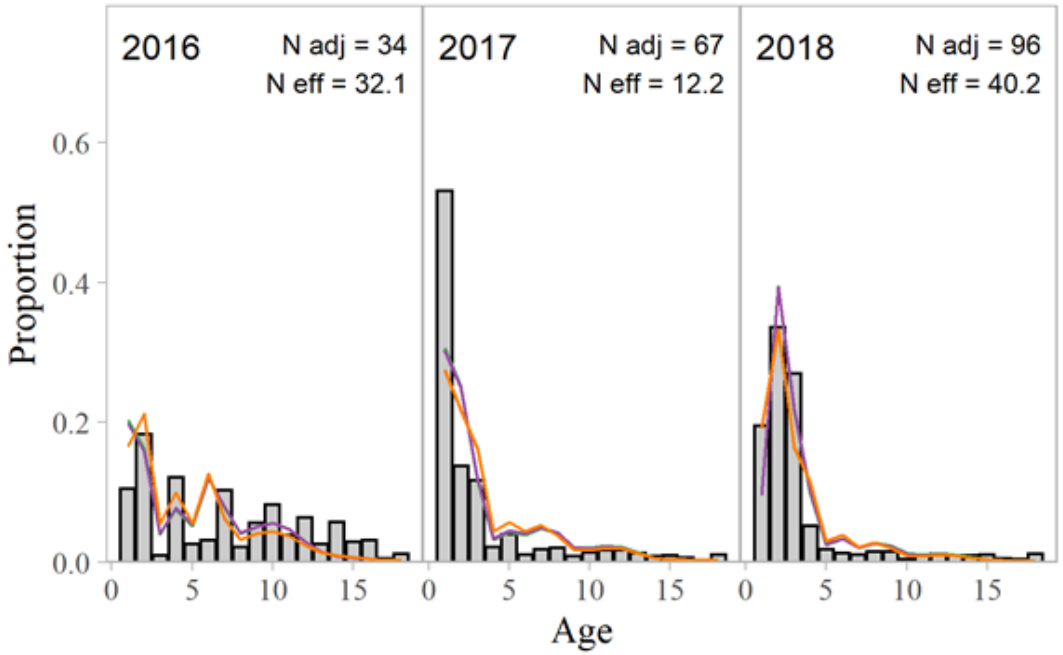

2009
N adj = 38
N eff = 52.8
2010
N adj = 52
N eff = 133.6
2011
N adj = 43
N eff = 27.1
2012
N adj = 48
N eff = 99.3
2013
N adj = 70
N eff = 82.9
2014
N adj = 28
N eff = 90.2
2015
N adj = 37
N eff = 29.4
2018
N adj = 20
N eff = 19.5
2019
N adj = 12
N eff = 16.9
Proportion
Age
KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2

Figure 9-32


Fishery Age Pearson Residuals
-2
0.1
2
Age (yr)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
2010
2011
2012
2013
2014
2015
2018
2019
Year


2016
N adj = 34
N eff = 32.1
2017
N adj = 67
N eff = 12.2
2018
N adj = 96
N eff = 40.2
Proportion
0.0
0.2
0.4
0.6
0
5
10
15
Age

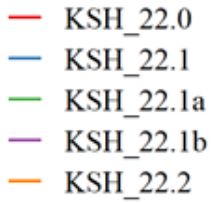
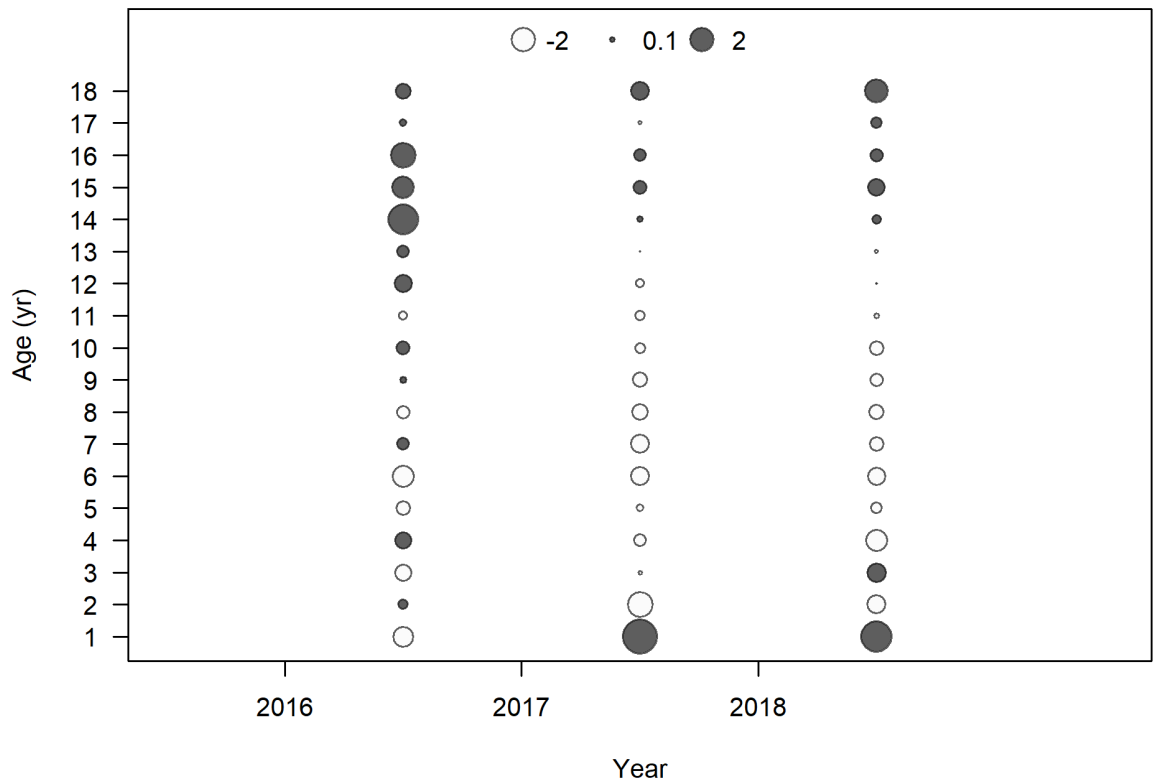
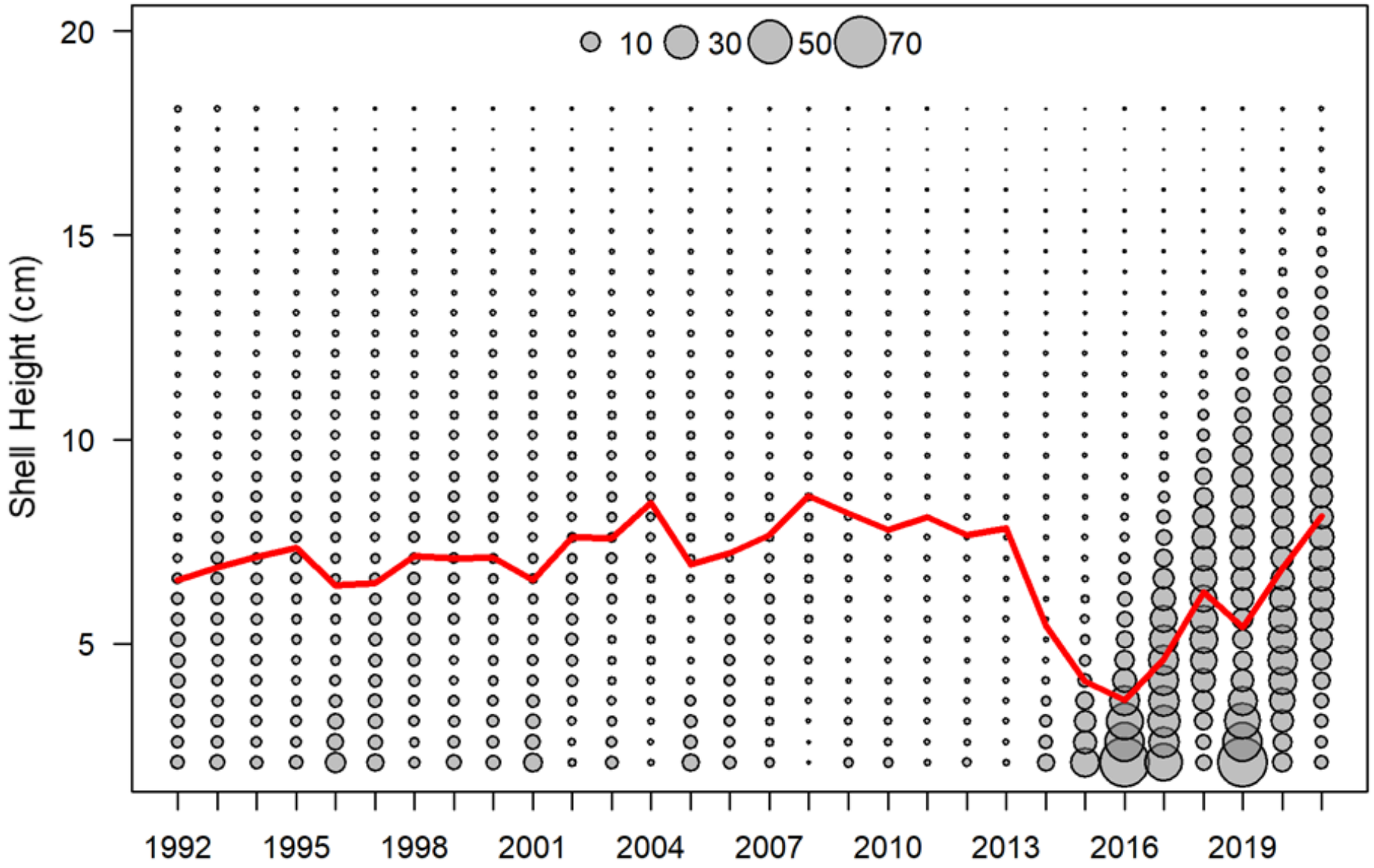

KSH_22.0
KSH_22.1
KSH_22.1a
KSH_22.1b
KSH_22.2

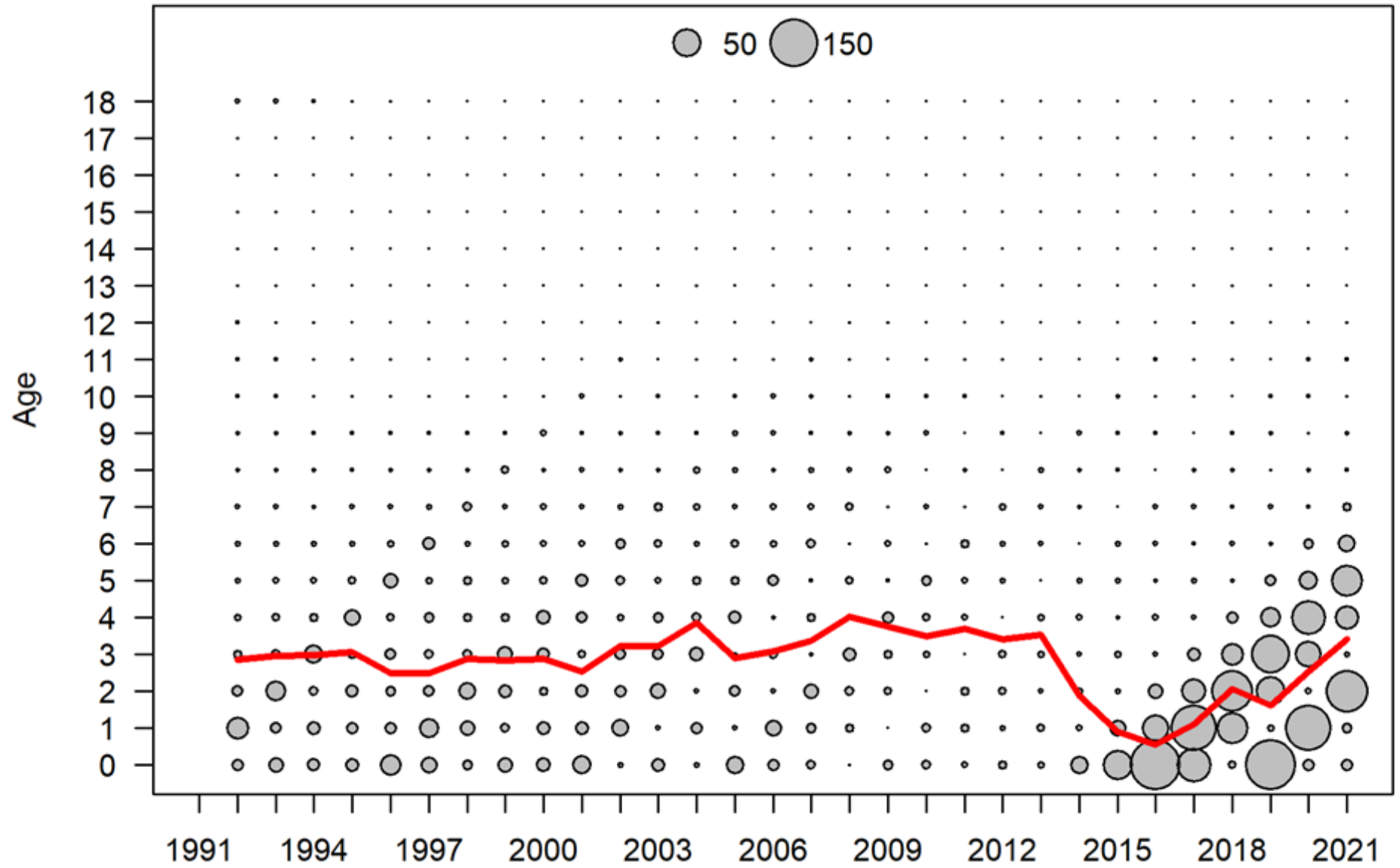
Figure 9-33


-2
0.1
2
Age (yr)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
2016
2017
2018
Year

Mid-Year Numbers at Size



Mid-Year Numbers at Age



Retrospective Analysis of KSH 22.1

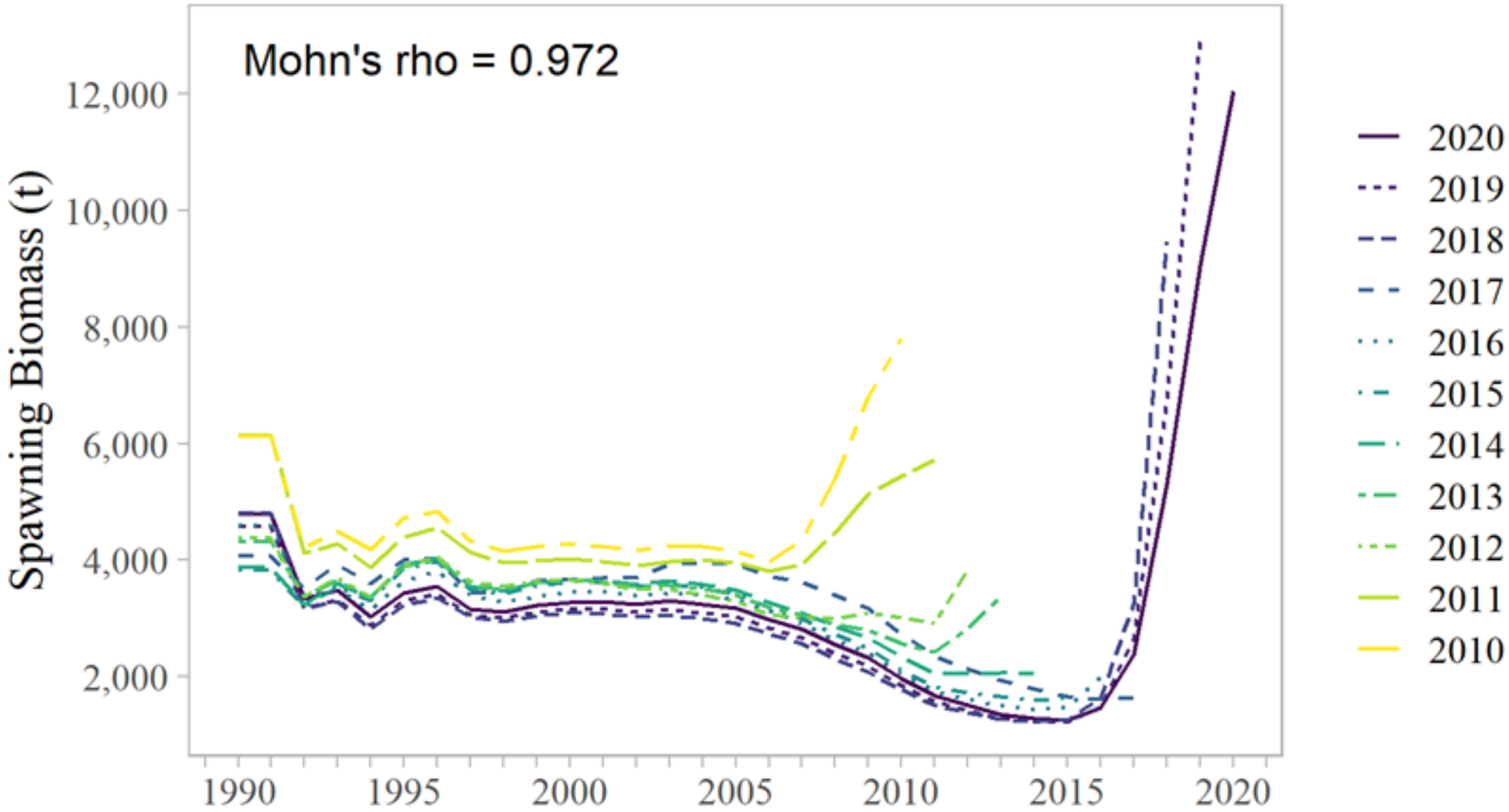


Figure 9-38

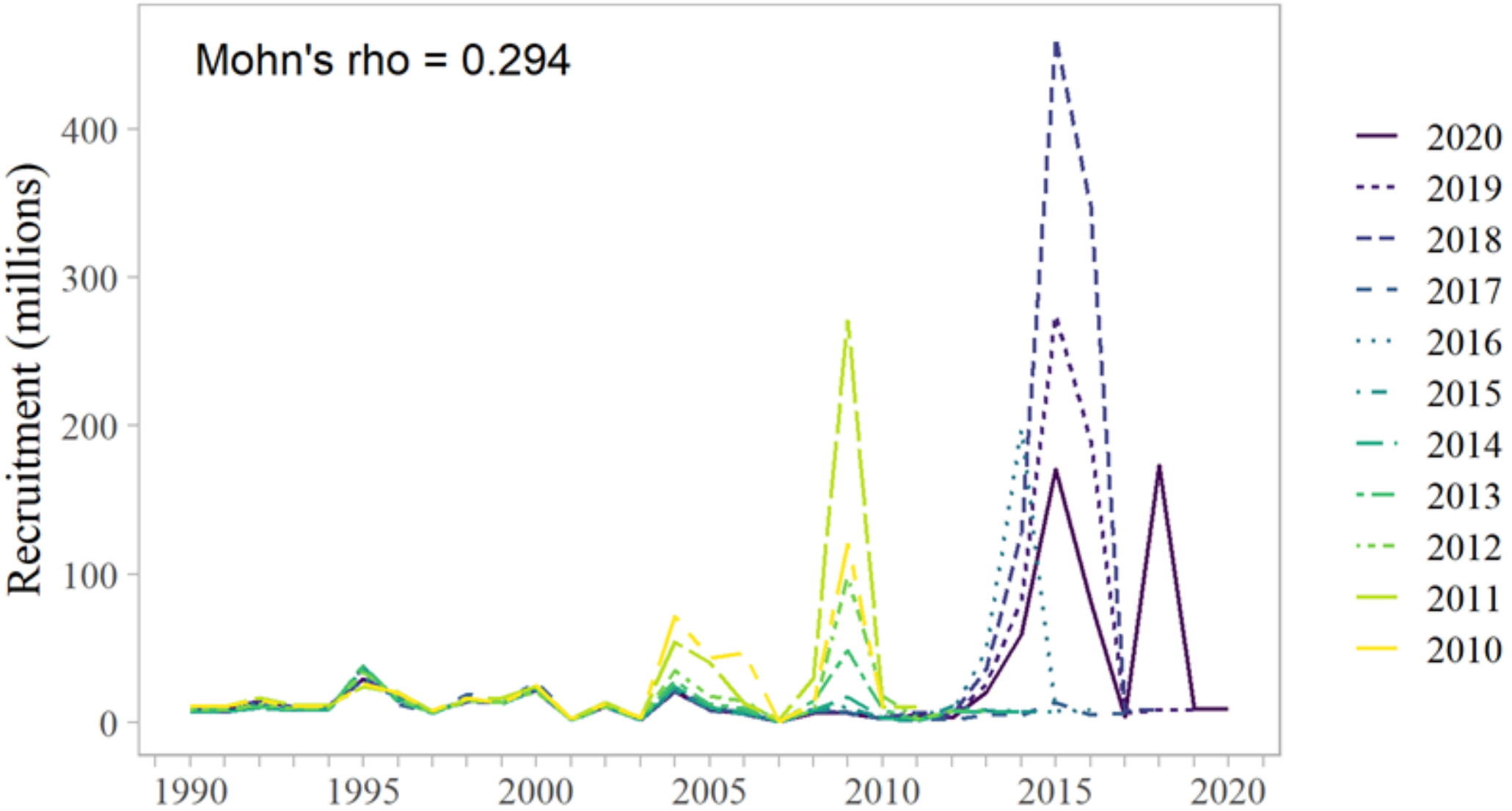

Mohn's rho = 0.294
Recruitment (millions)
0
100
200
300
400
1990
1995
2000
2005
2010
2015
2020
2020
2019
2018
2017
2016
2015
2014
2013
2012
2011
2010

Figure 9-39

Conclusions

Stock Synthesis appears to be a viable tool for AK scallop assessment, but needs refinement

- Strong retrospective pattern in both KAM and KSH models
- Likely some mis-specification

M has big impact on scaling SSB and model fit.

- Larger *M* ~ increased SSB and better fit
- *M* = 0.24 Is likely too high, Then et al. (2015) suggests 0.18 – 0.22 for max age of 29 yr

More research is to implement ADF&G trawl survey data for KSH…*priority??*

What's Next

Should assessment development continue with Stock Synthesis (ie or other integrated age/size structured model)?

- Makes full use of available data
- Requires more data, more time, more informed review, possibly more frequent
- Age comp data is more limited in some harvest areas, size is easy to collect
- Refine KAM/KSH models and/or work outwards?

Needs:

- Data recovery – need to be able to make use of pre-2009 observer data
- Discard estimates
- Revisit CPUE standardization – critical review
- Better understanding of connectivity (ie. one stock, one model, multiple regions)