An assessment for eastern Bering Sea snow crab

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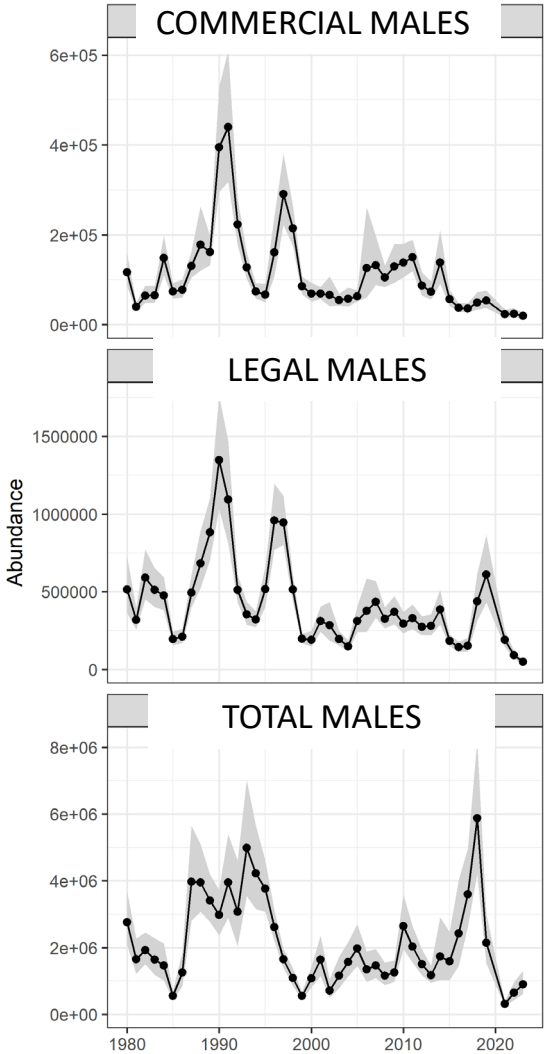
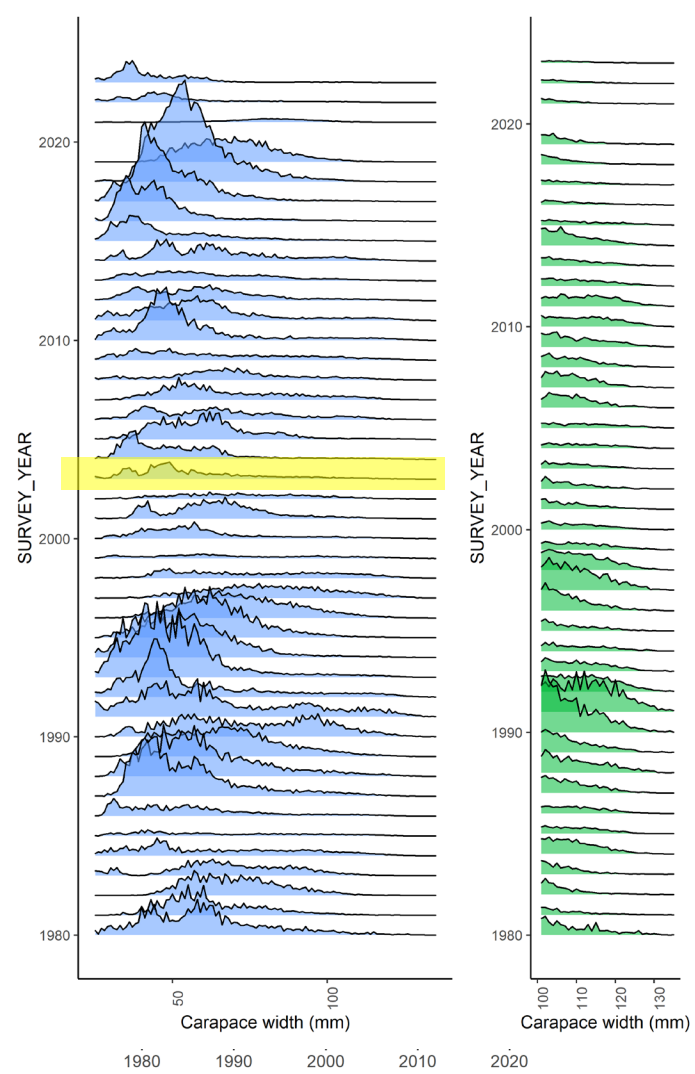
Alaska Fishery Science Center
September 14, 2023


2100 LBS AT 25FT
2100 LBS AT 50FT



- Commercially preferred males (>101 mm) at another historical low

- Slight uptick in total males, but all of them are still small and four or more years until fishable size.



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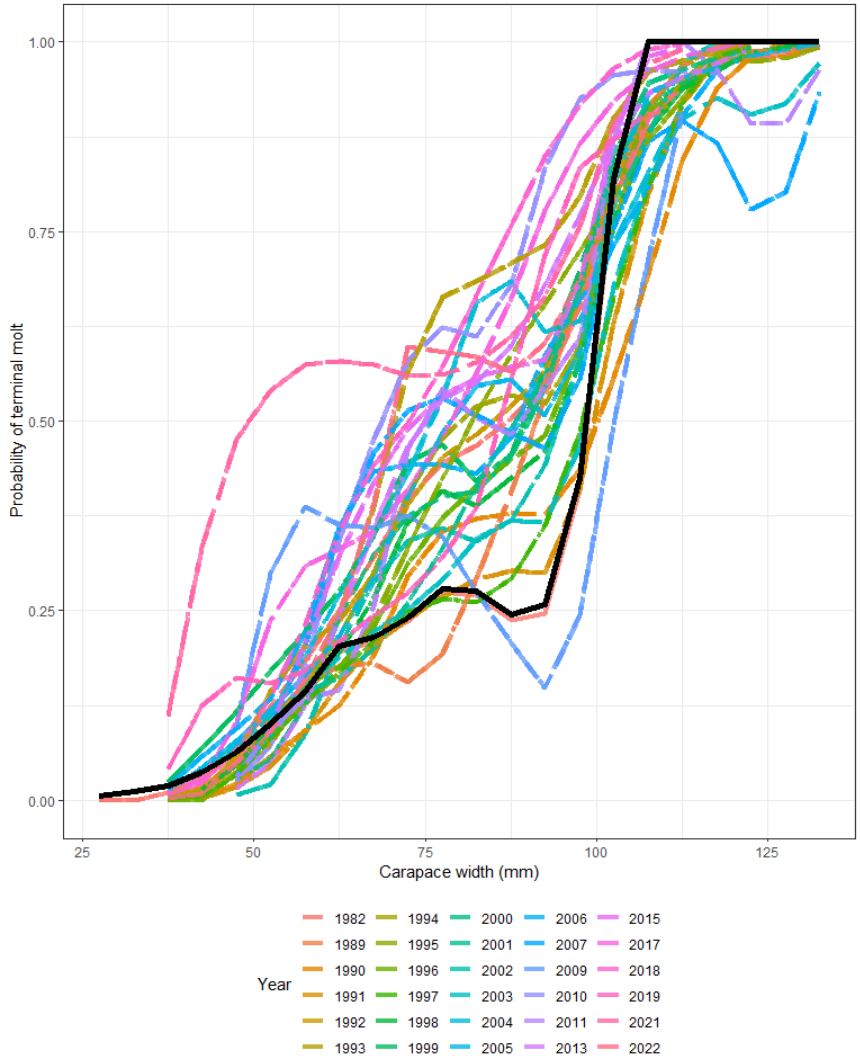
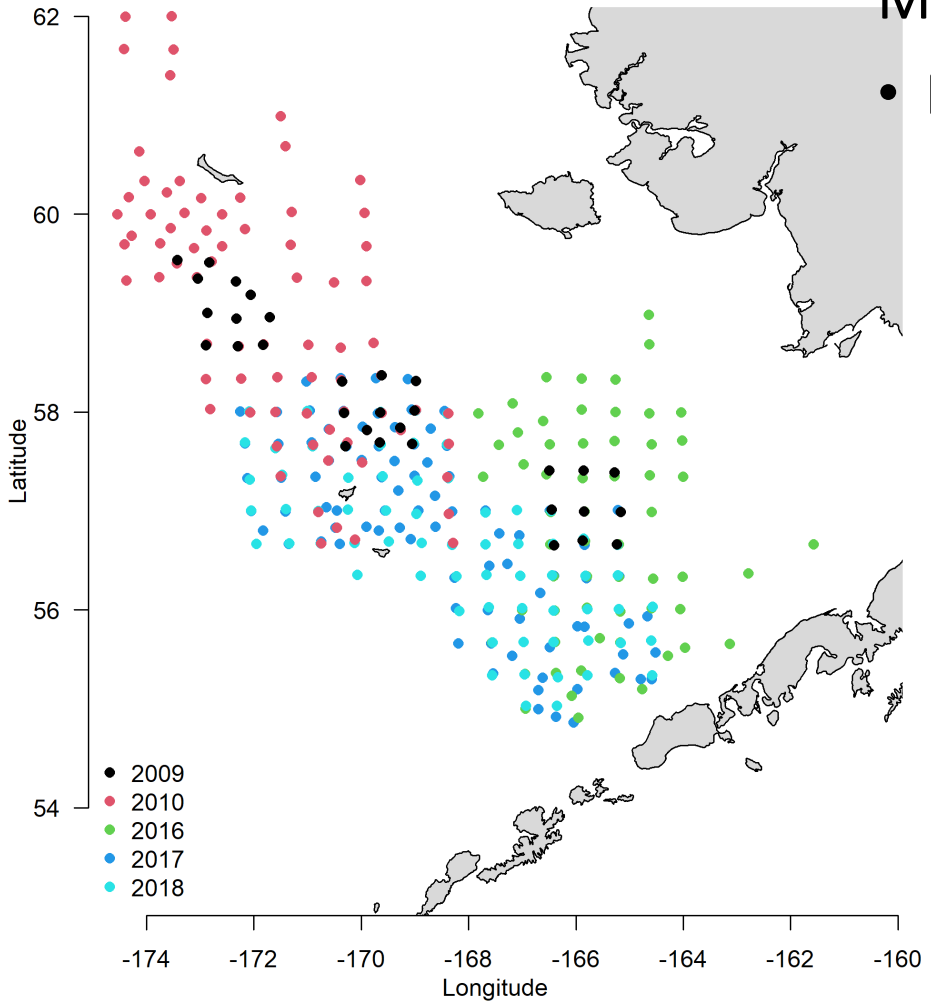
TWO DECISIONS

- Model choices
  - Biological assumptions
  - Treatment of data
- Management choices
  - Tier placement
  - Currency of management



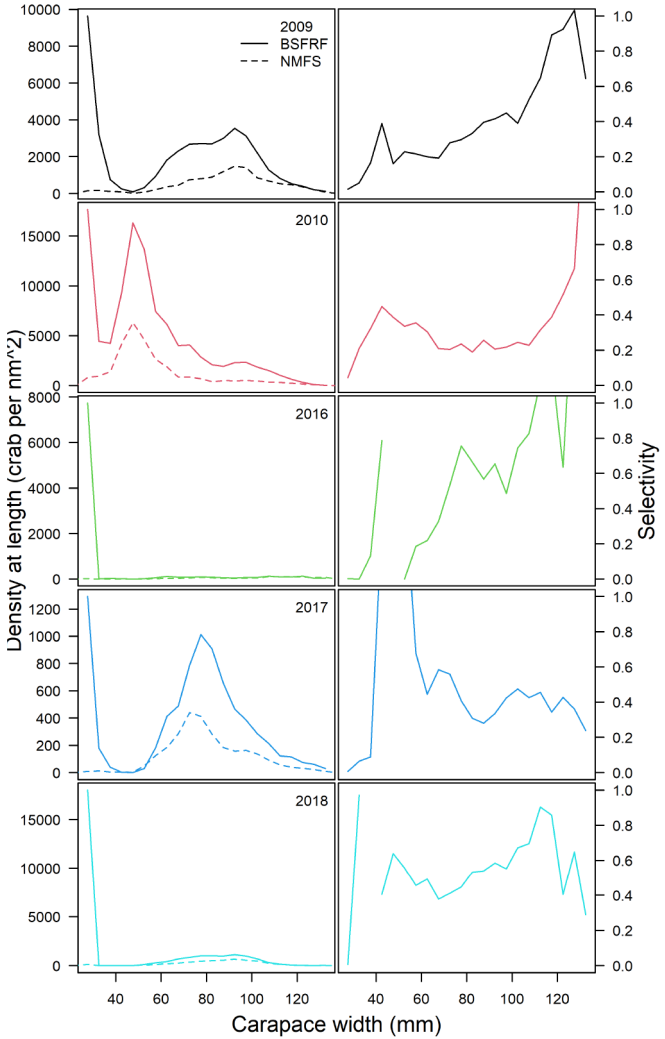
MODEL CHANGES:

- Inputting the observed probability of having undergone terminal molt
  - Growth stops after a molt to maturity
  - What size this happens at has large effects on reference points
  - Observations are made in the survey and used to split the data into ‘mature’ and ‘immature’



MODEL CHANGES:

- BSFRF data as priors
  - Previously input as additional survey, but the fitting process has a lot of flexibility
  - Previously assumed to be logistic, but now two studies suggest this isn't the case
  - This can increase the estimated exploitable biomass over the survey observation



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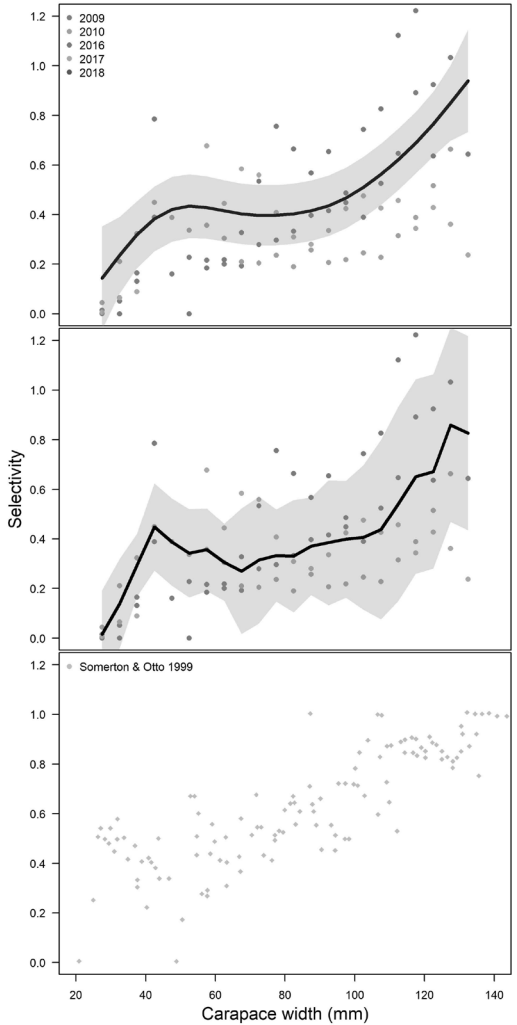

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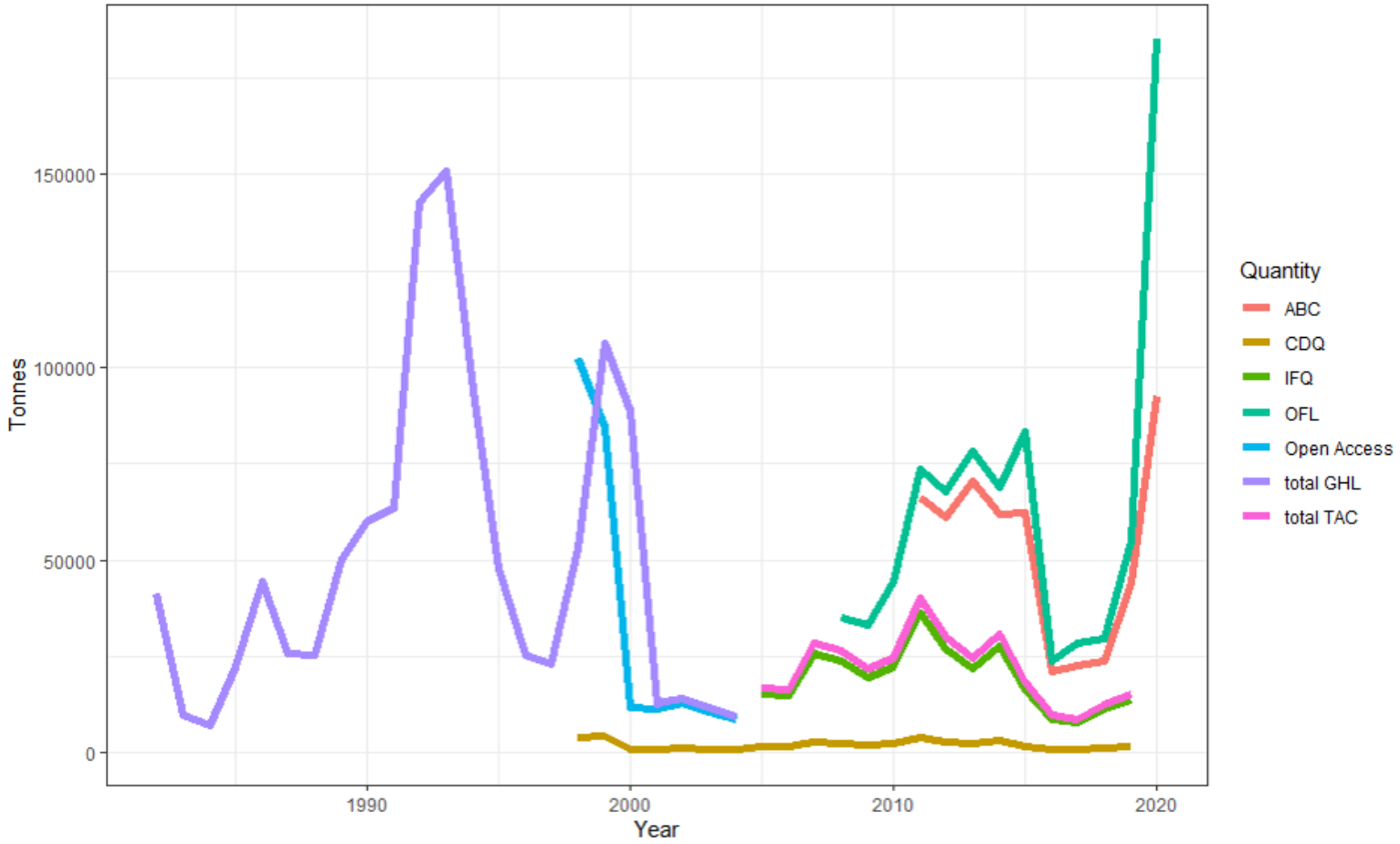
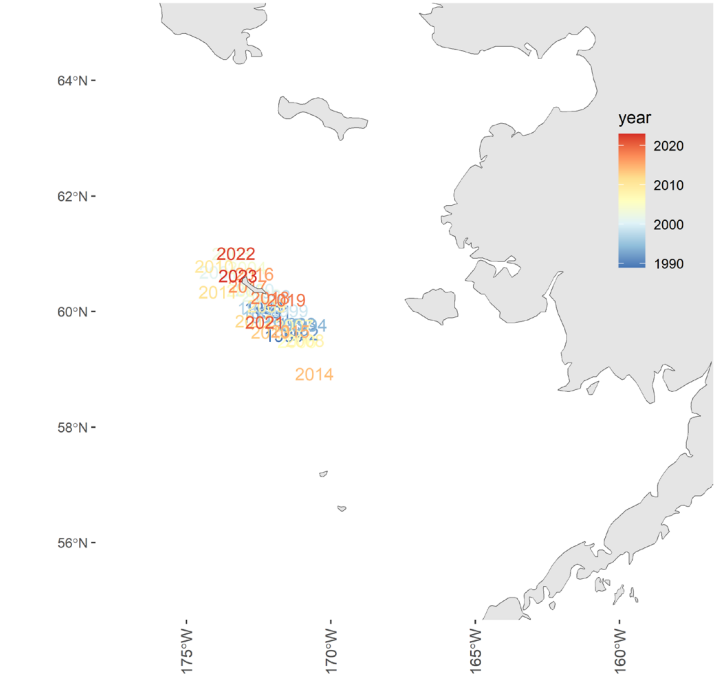
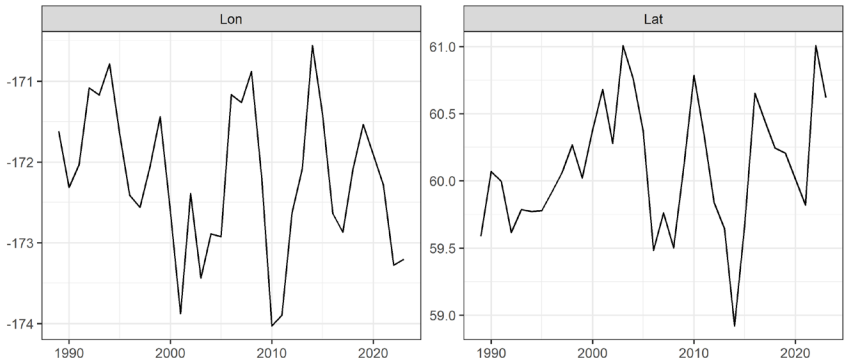
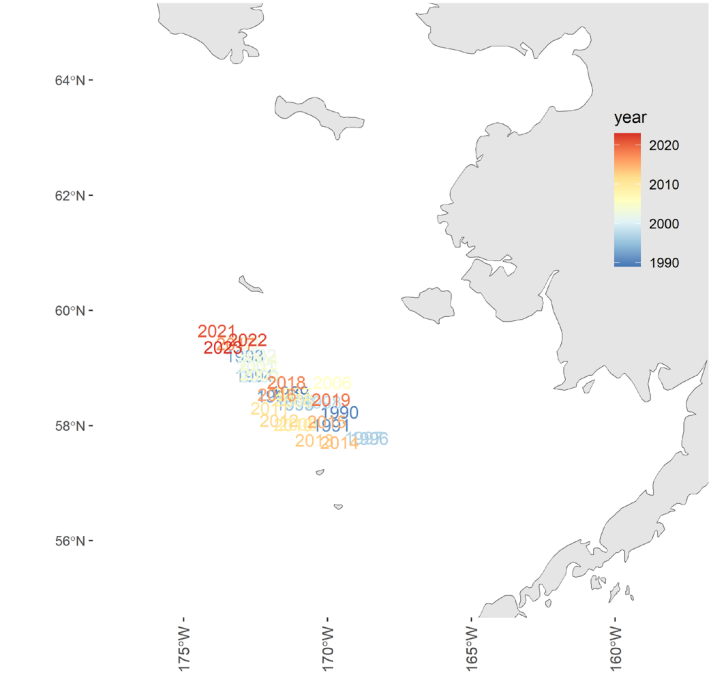
Federal vs. State HCRS

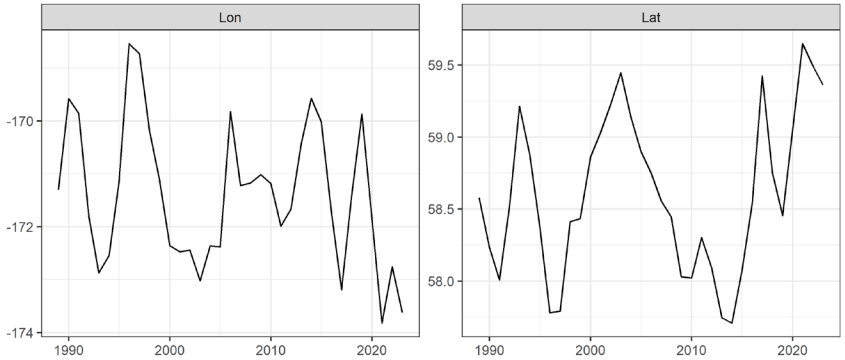




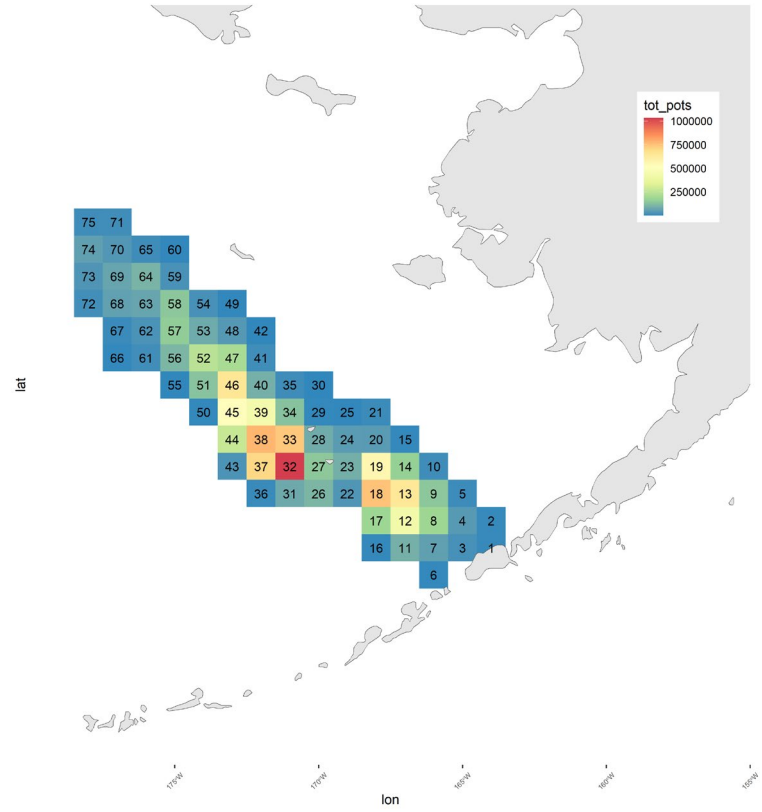


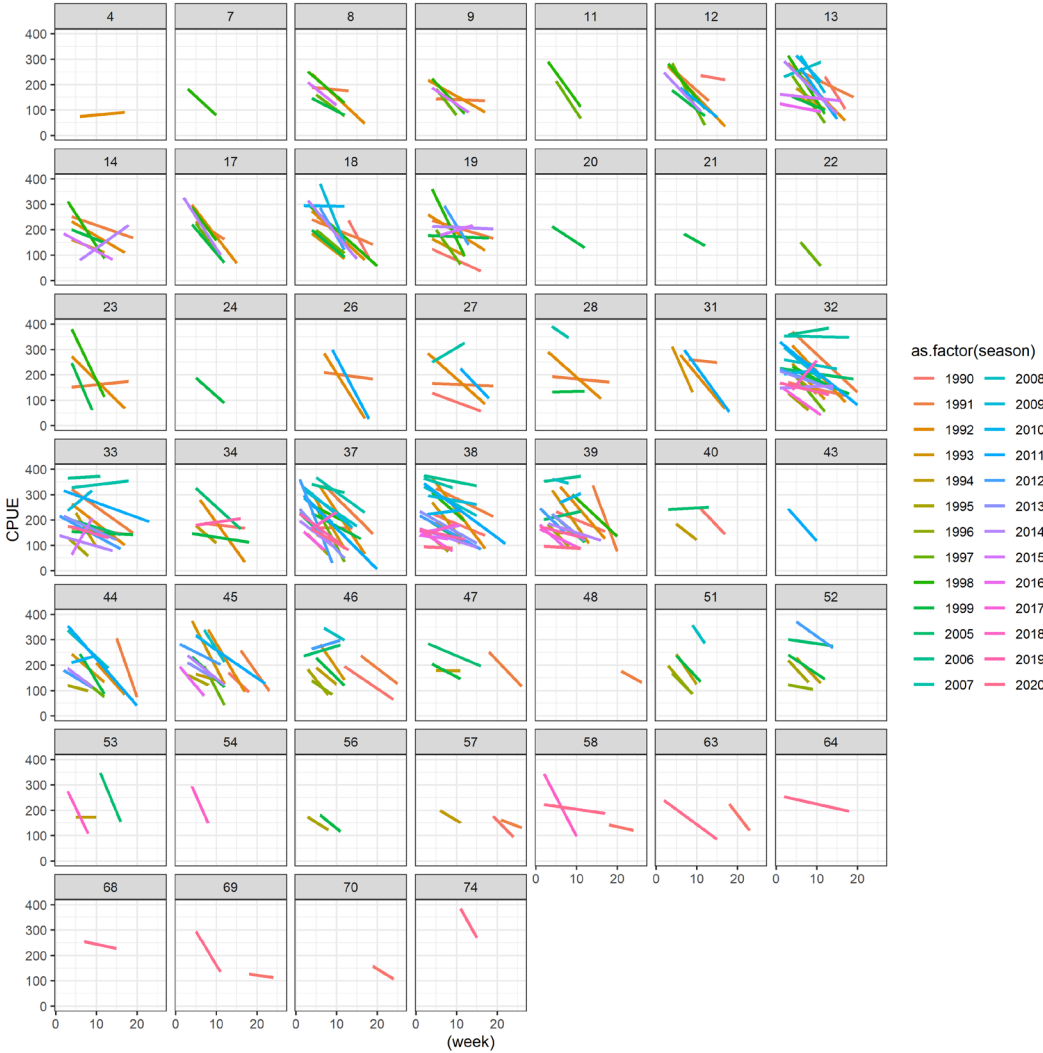
Centroids of abundance for males 45-85 mm carapace width. Map shows the centroid in space by year; blue colors are farther in the past. Bottom figures isolate the latidudinal and longitudinal components.





Centroids of abundance for males greater than 101 mm carapace width. Map shows the centroid in space by year; blue colors are farther in the past. Bottom figures isolate the latidudinal and longitudinal components.


tot_pots
1000000
750000
500000
250000
75 71
74 70 65 60
73 69 64 59
72 68 63 58 54 49
67 62 57 53 48 42
66 61 56 52 47 41
55 51 46 40 35 30
50 45 39 34 29 25 21
44 38 33 28 24 20 15
43 37 32 27 23 19 14 10
36 31 26 22 18 13 9 5
17 12 8 4 2
16 11 7 3 1
6
lat
lon
175°W
170°W
165°W
160°W
155°W


4
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63
64
68
69
70
74
CPUE
(week)
0
100
200
300
400
10
20
as.factor(season)
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2005
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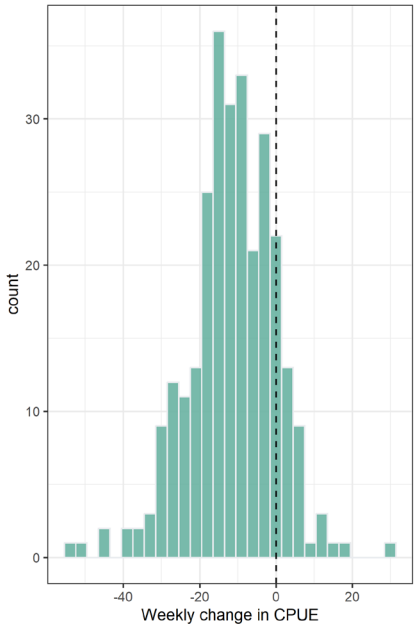
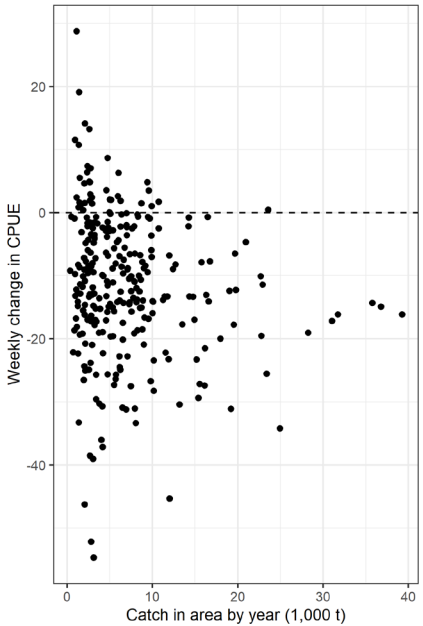
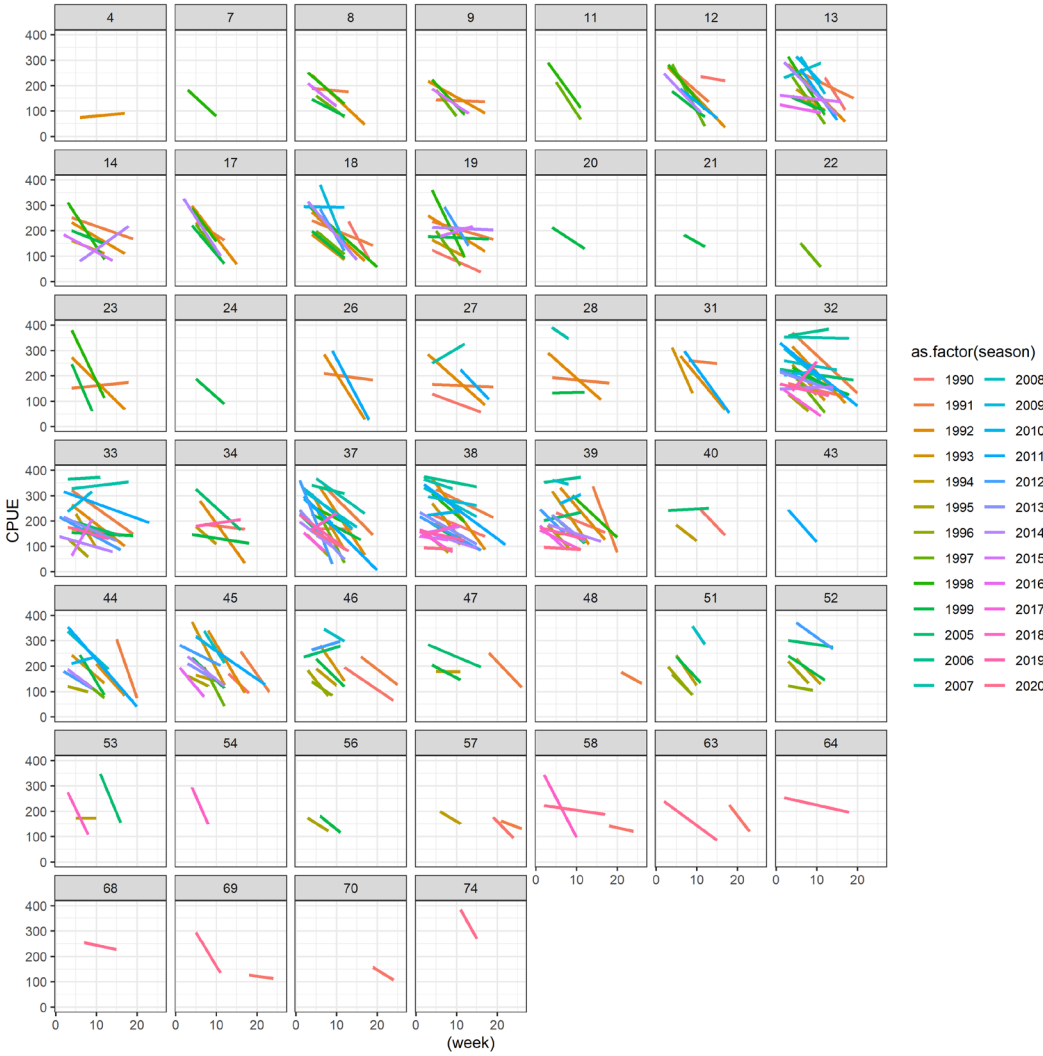
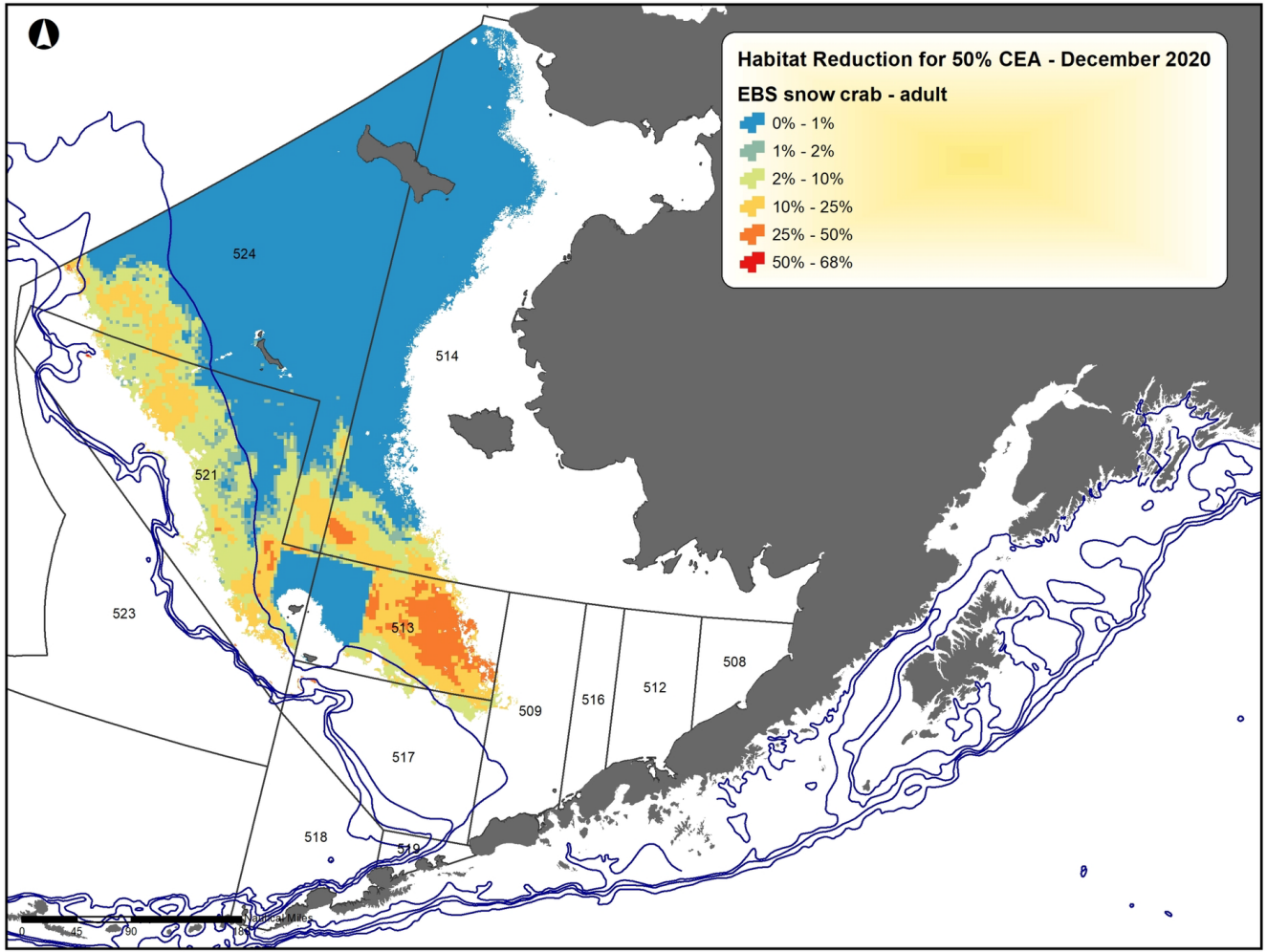
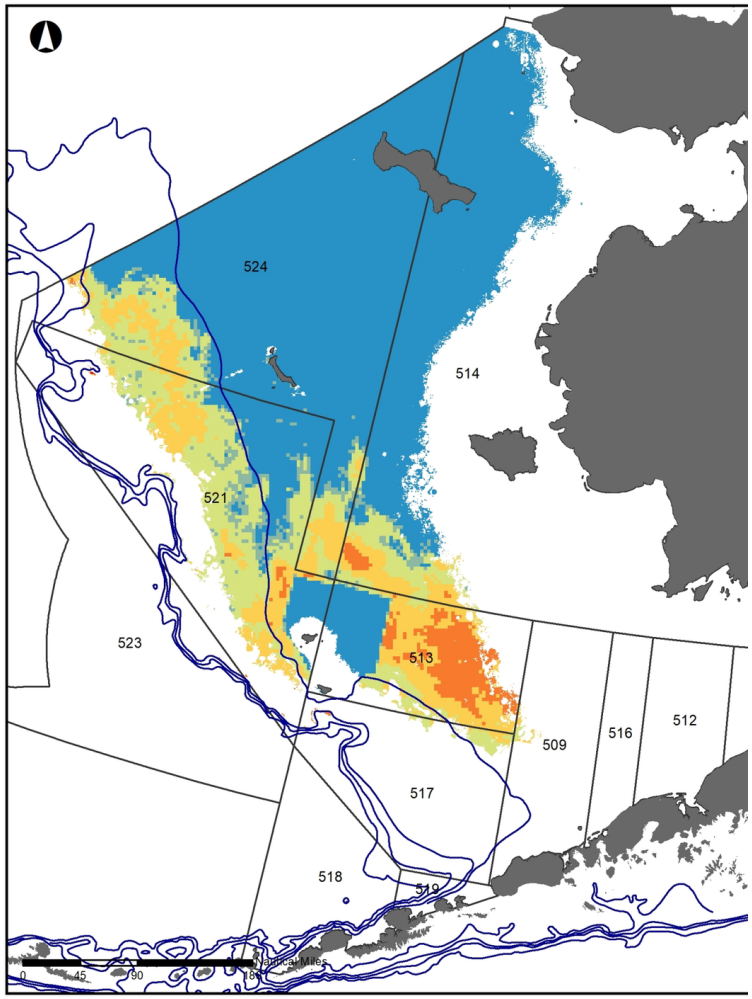
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


count
Weekly change in CPUE

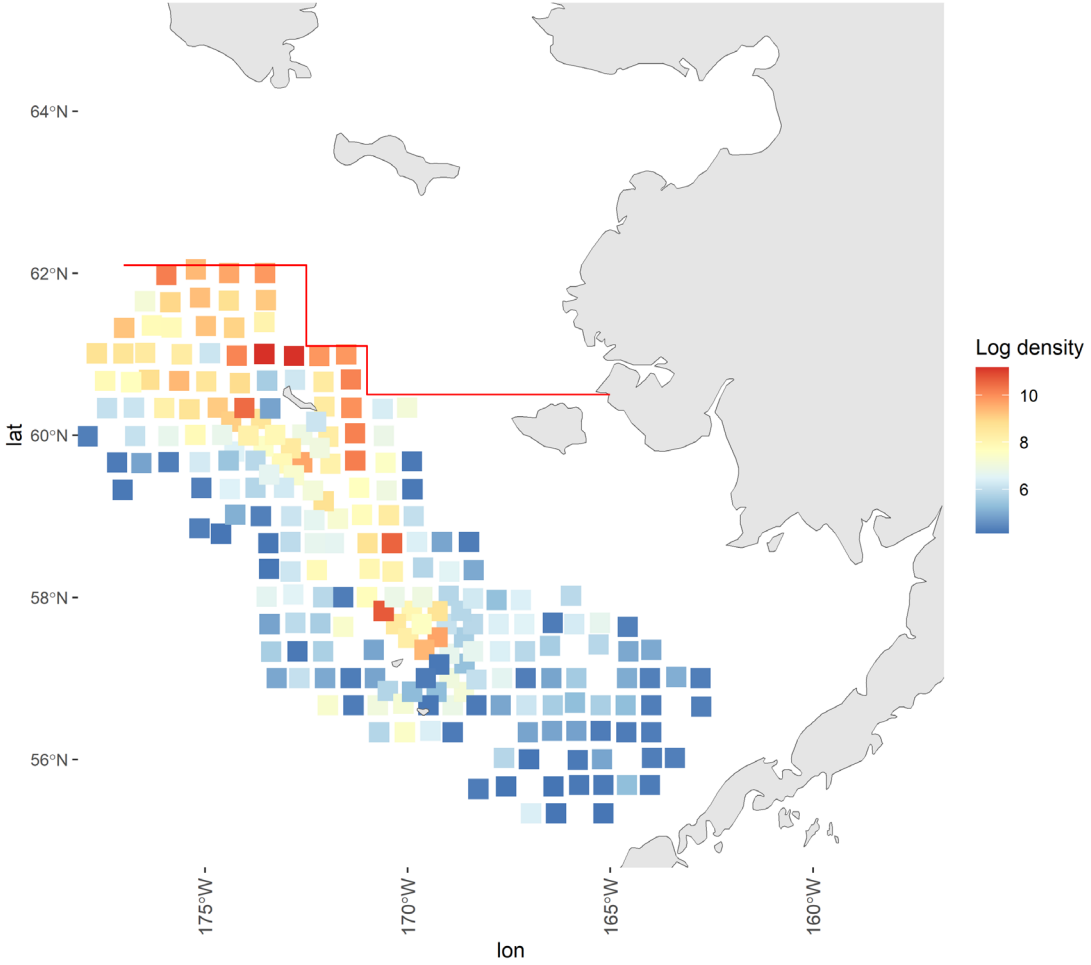

Weekly change in CPUE
Catch in area by year (1,000 t)


CPUE
(week)
as.factor(season)
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

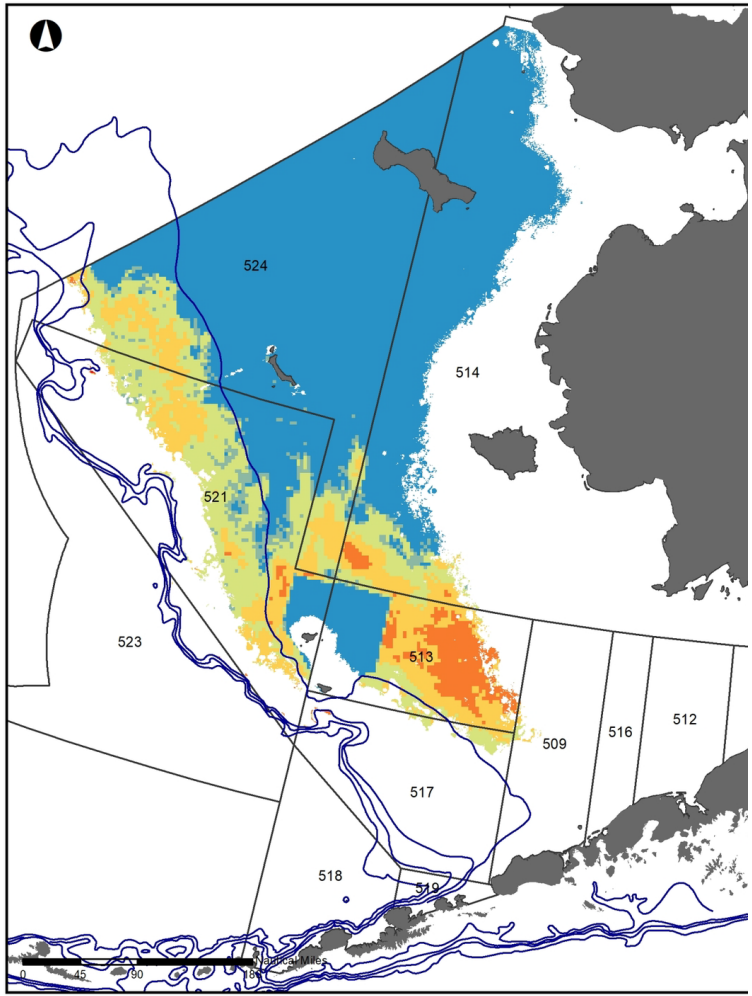

Habitat Reduction for 50% CEA - December 2020
EBS snow crab - adult
0% - 1%
1% - 2%
2% - 10%
10% - 25%
25% - 50%
50% - 68%
524
514
521
523
513
508
512
516
509
517
518
519
Nautical Miles
0
45
90
180

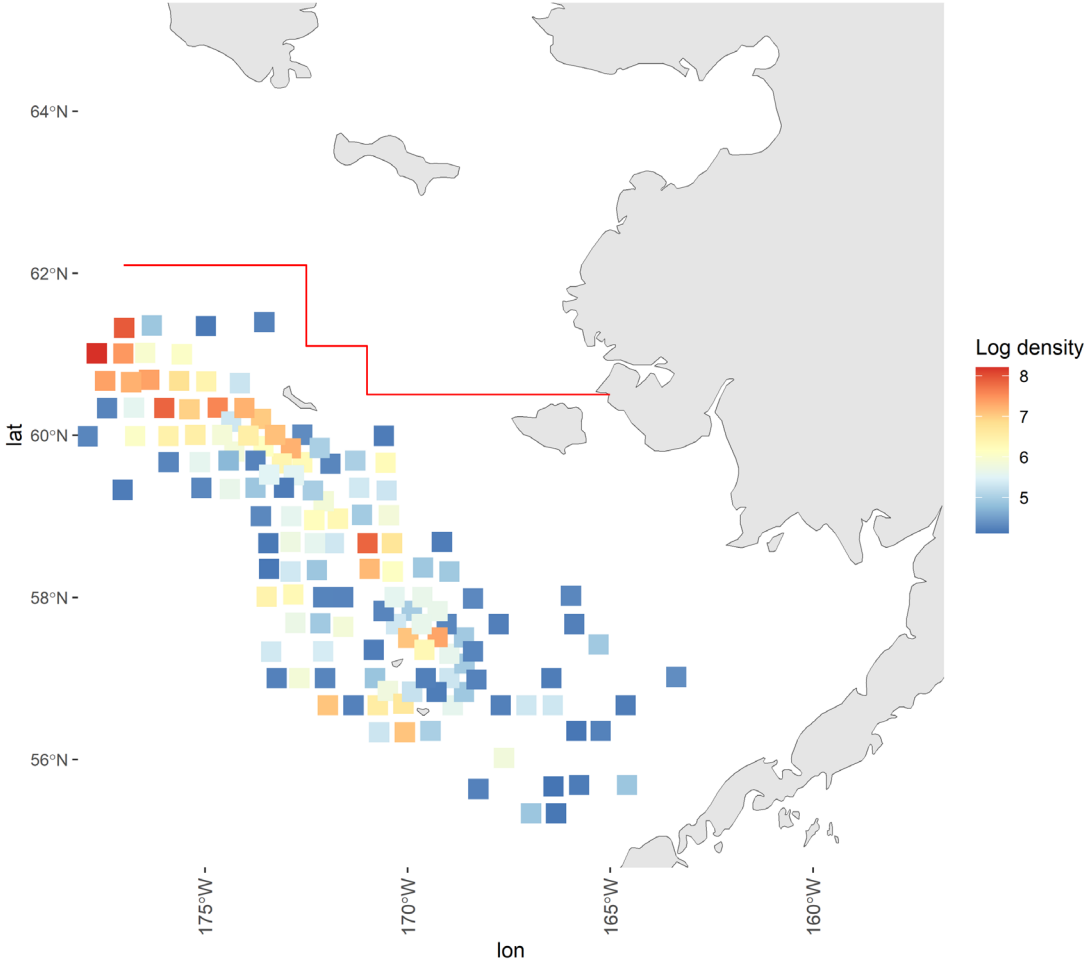


TOTAL MALE SNOW CRAB 2023



>101MM MALE SNOW CRAB 2023

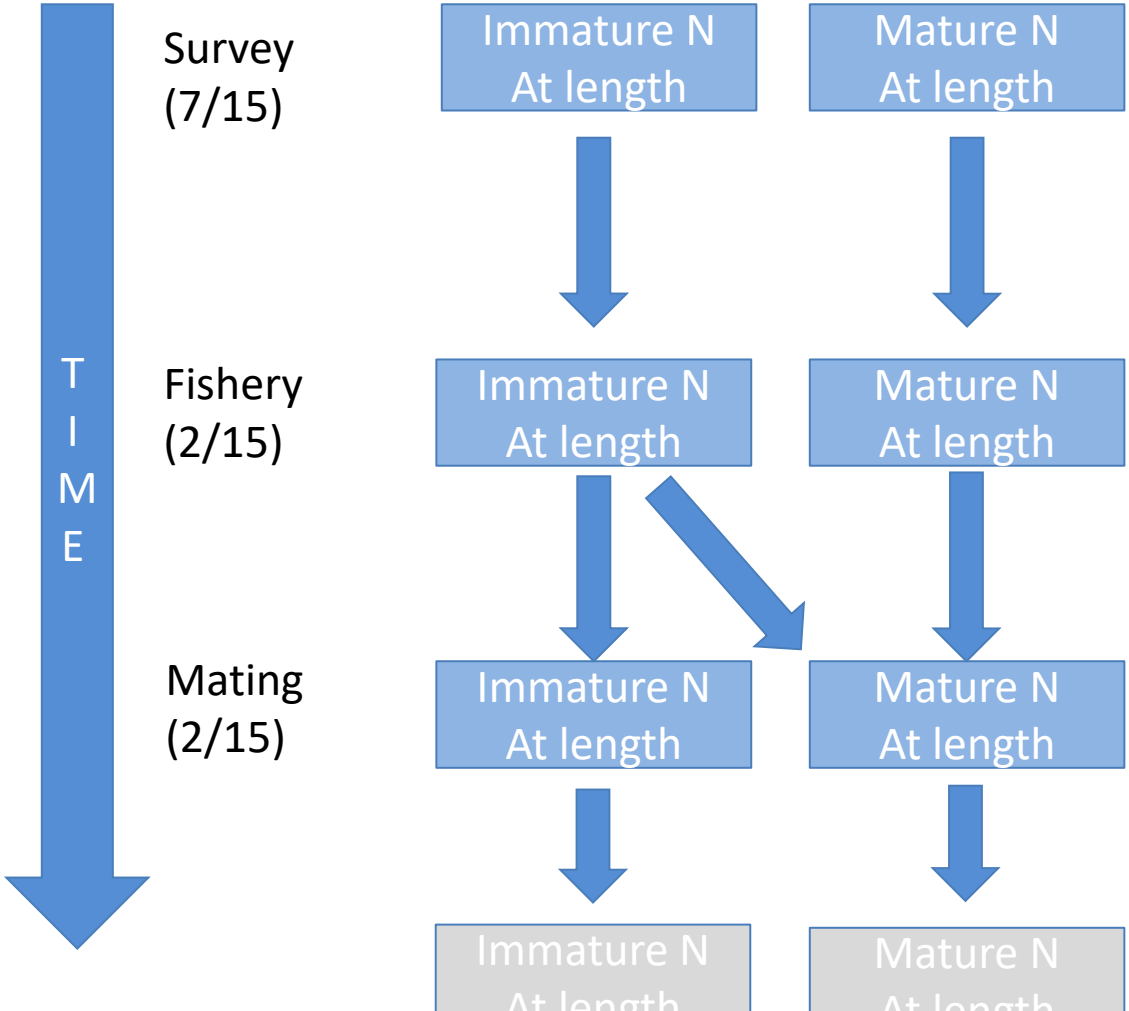


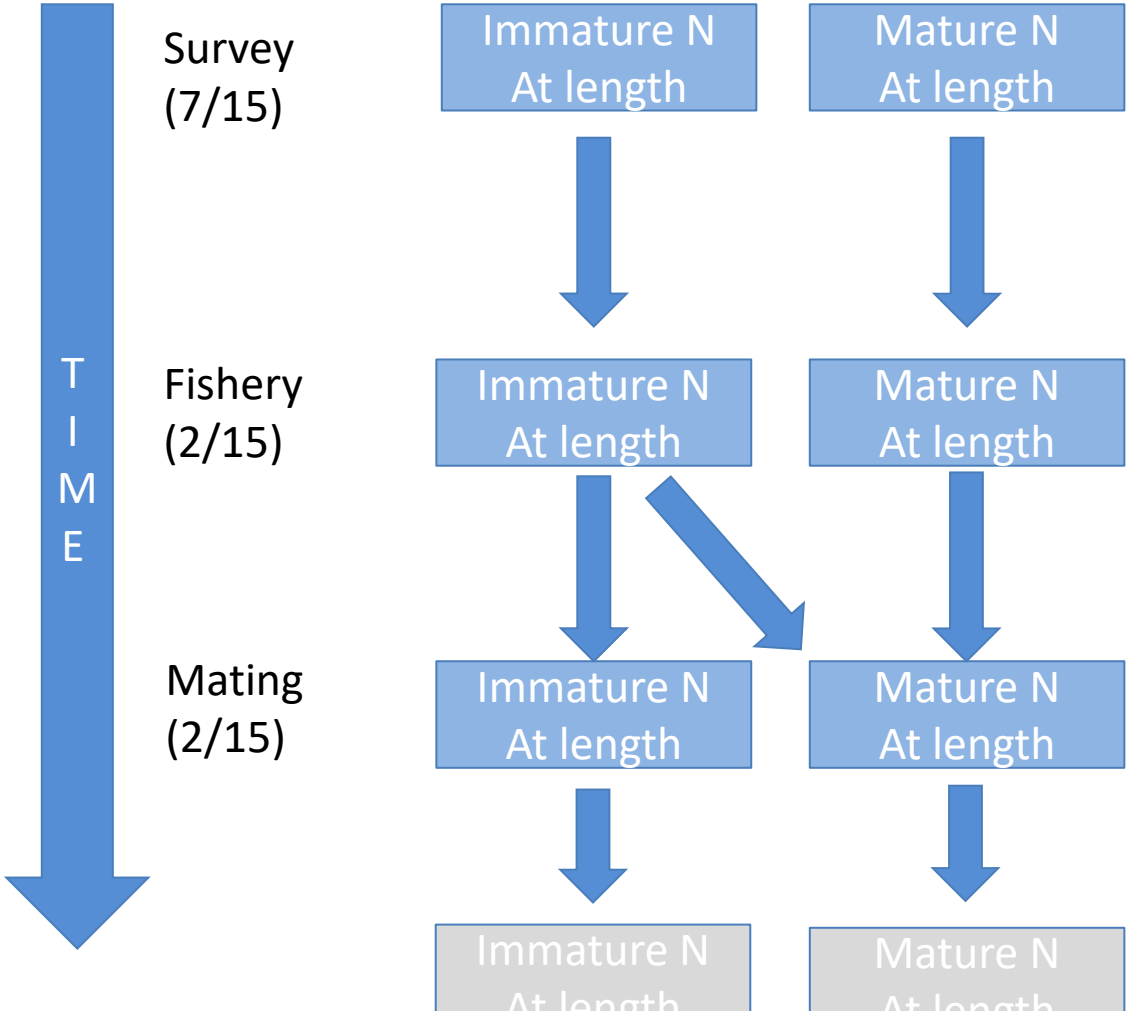


SSC and CPT comments + author responses

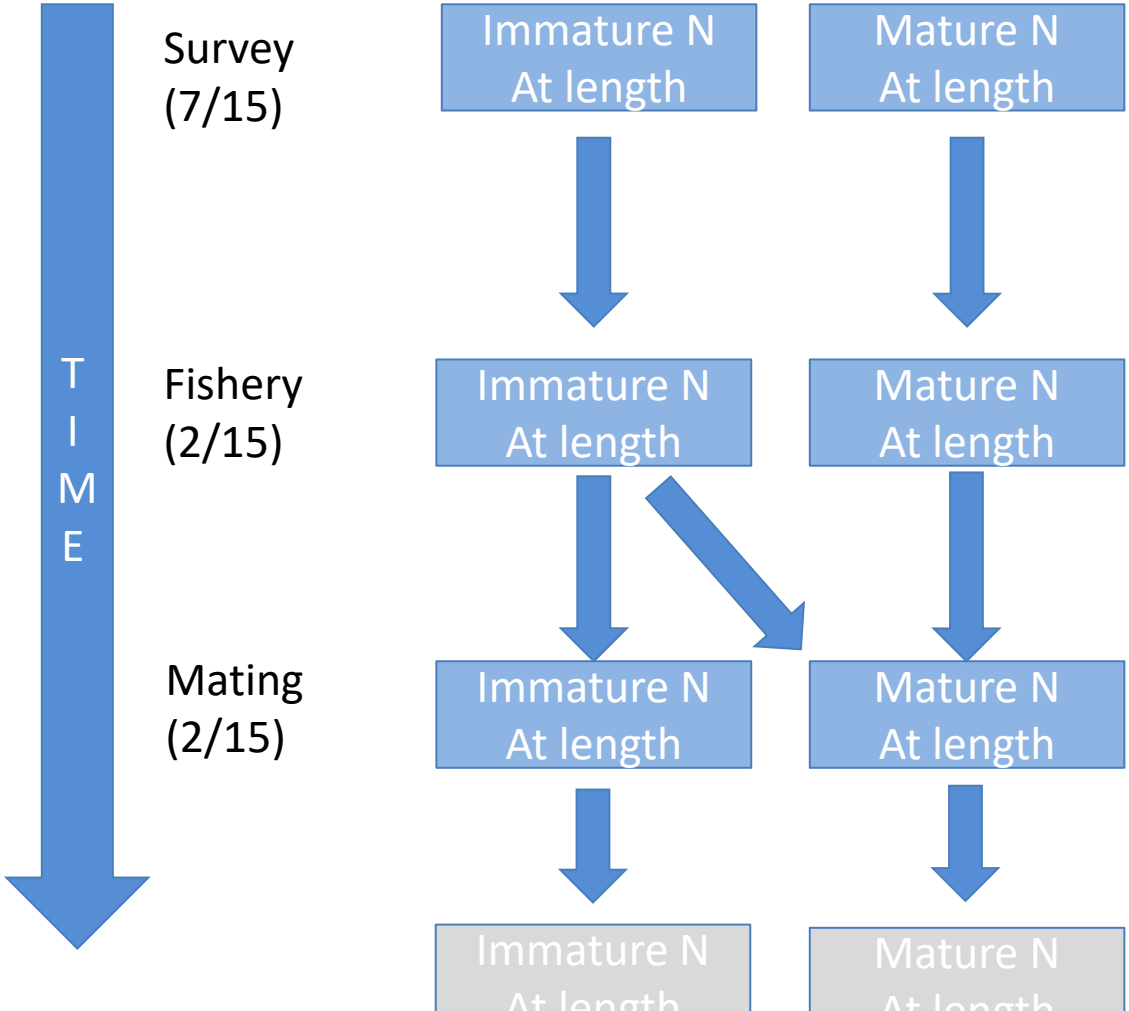
SSC comment: F35% fishing mortality rate no longer results in a meaningful conservation constraint on the fishery for snow crab. To evaluate a potential alternative to the status quo, the SSC recommends that OFL and ABC estimates be provided for a modified Tier 3 approach for each model carried forward. This approach has the following characteristics: the OFL is calculated by replacing F35% in the Tier 3 harvest control rule by the model estimate of natural mortality. Biomass reference levels and status determination would be calculated using MMB as usual for Tier 3. The SSC requests evaluation of this approach by the assessment author and the CPT.

(additional analysis within)

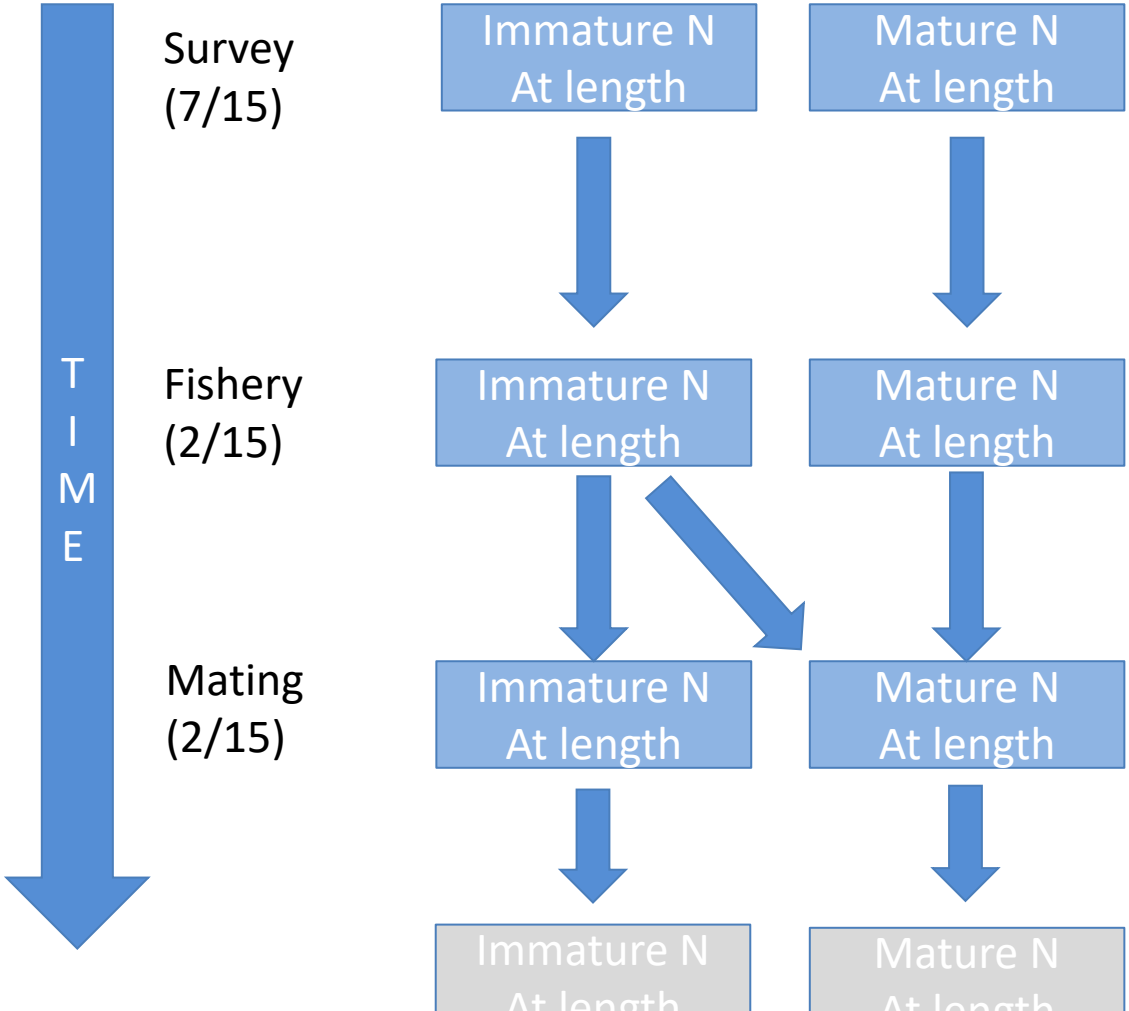

TIME
Survey
(7/15)
Fishery
(2/15)
Mating
(2/15)
Immature N
At length
Mature N
At length
Immature N
At length
Mature N
At length
Immature N
At length
Mature N
At length
Immature N
Mature N



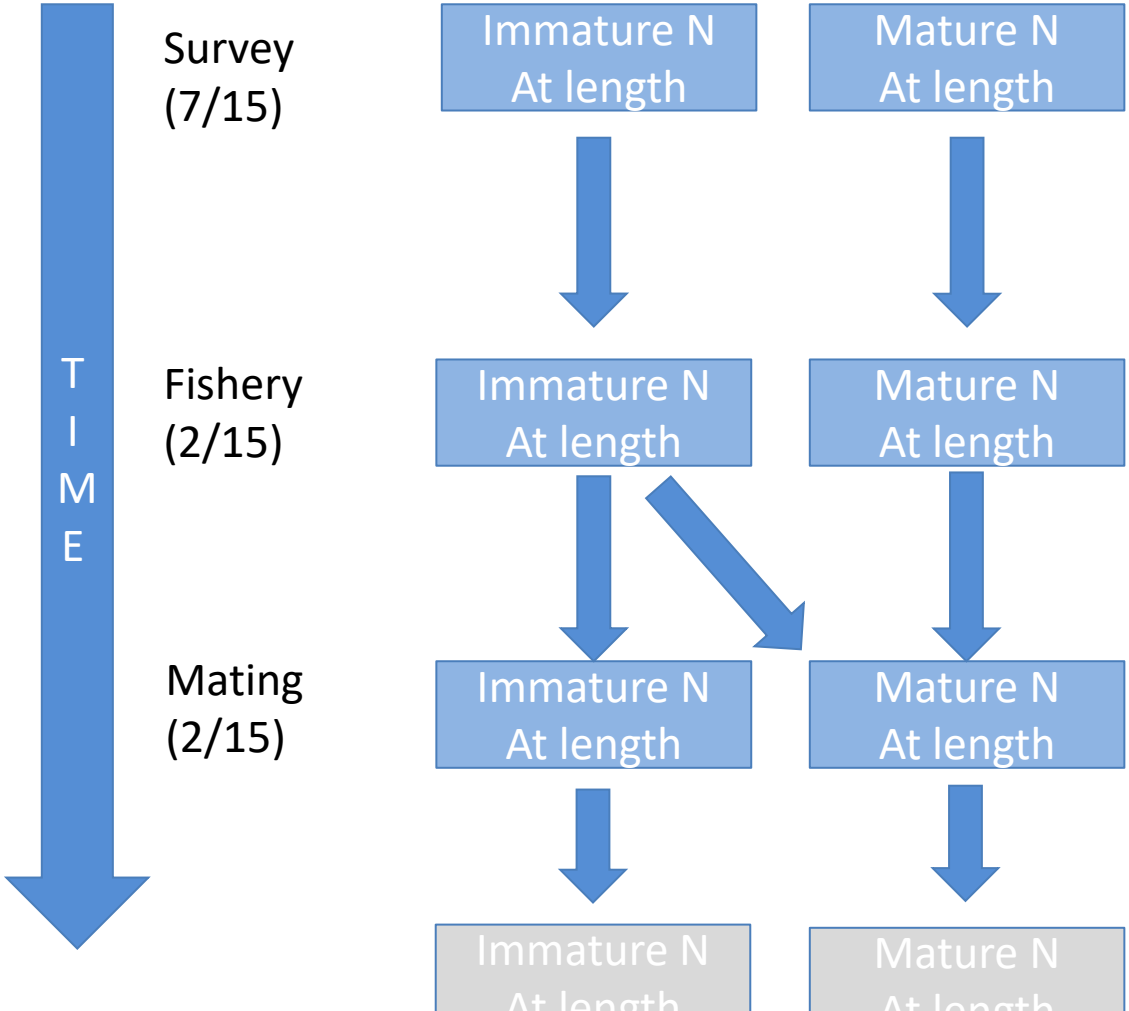
Survey data collected with an estimated selectivity



Natural mortality occurs (estimated by sex and maturity state + events)

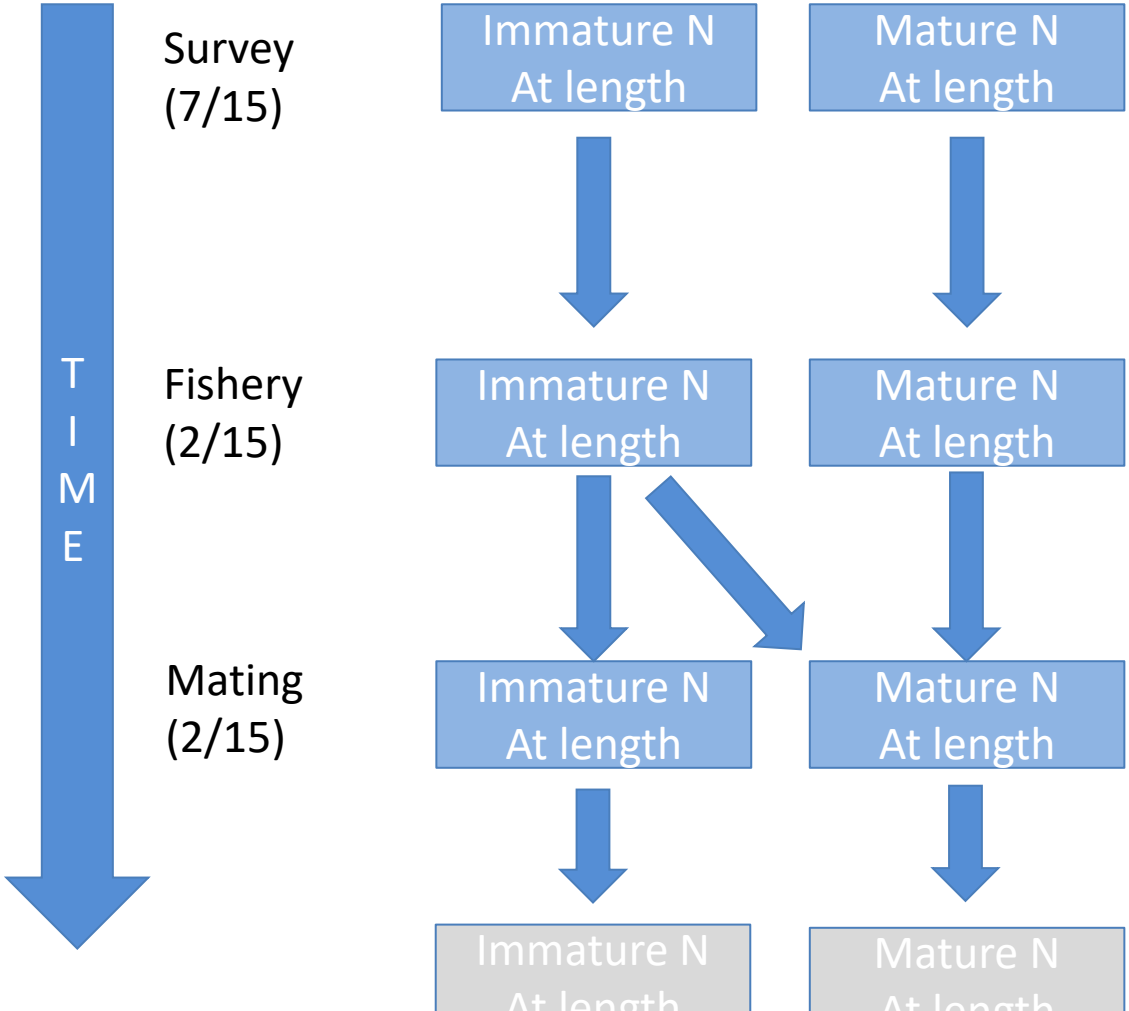


Directed and non-directed fishery occur with sex and fishery specific selectivity.

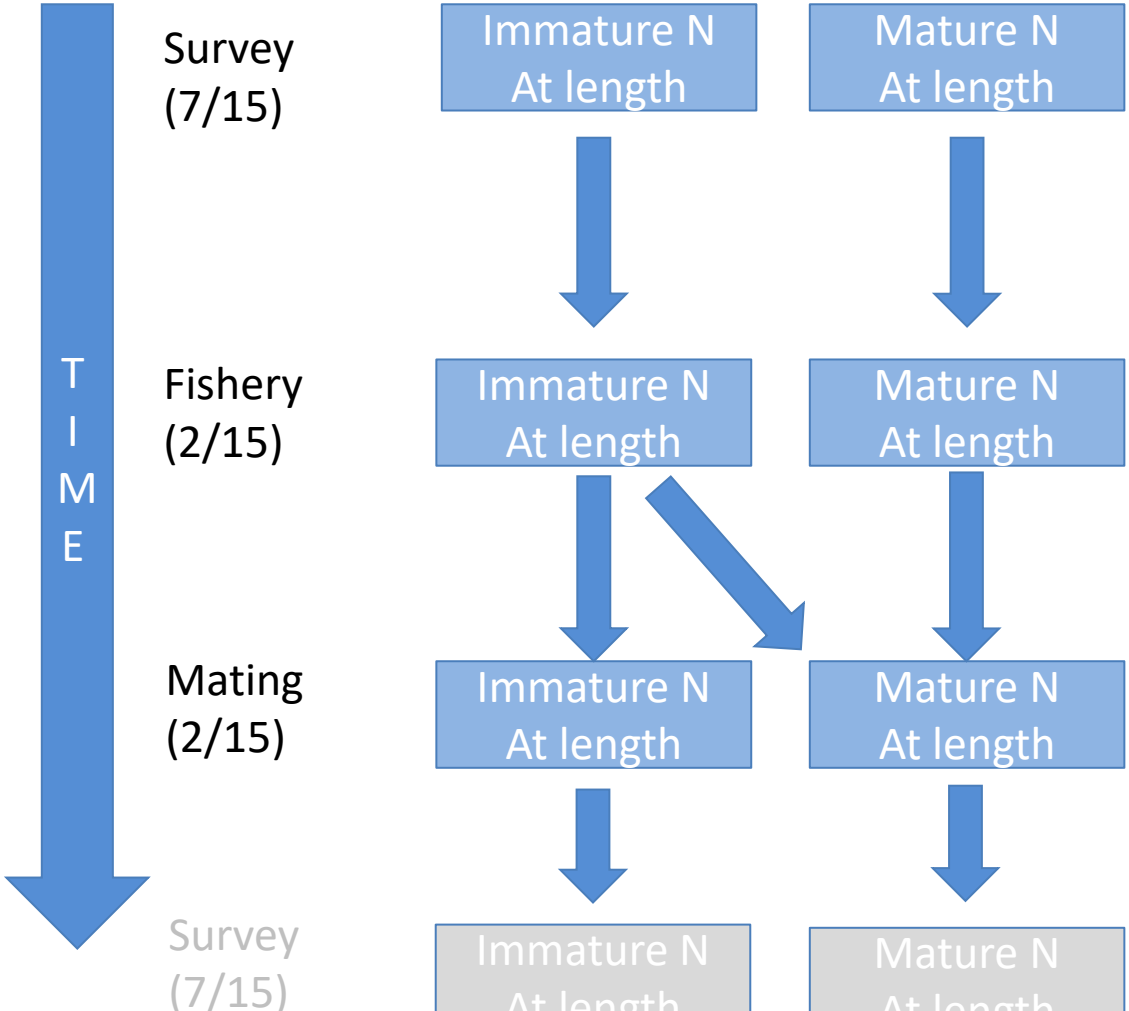


Growth occurs (linear molt increment by sex)

After growth previously immature animals are allocated to immature or mature size bins based on a probability of having undergone terminal molt.



Recruitment occurs and is primarily allocated to the first three size bins.



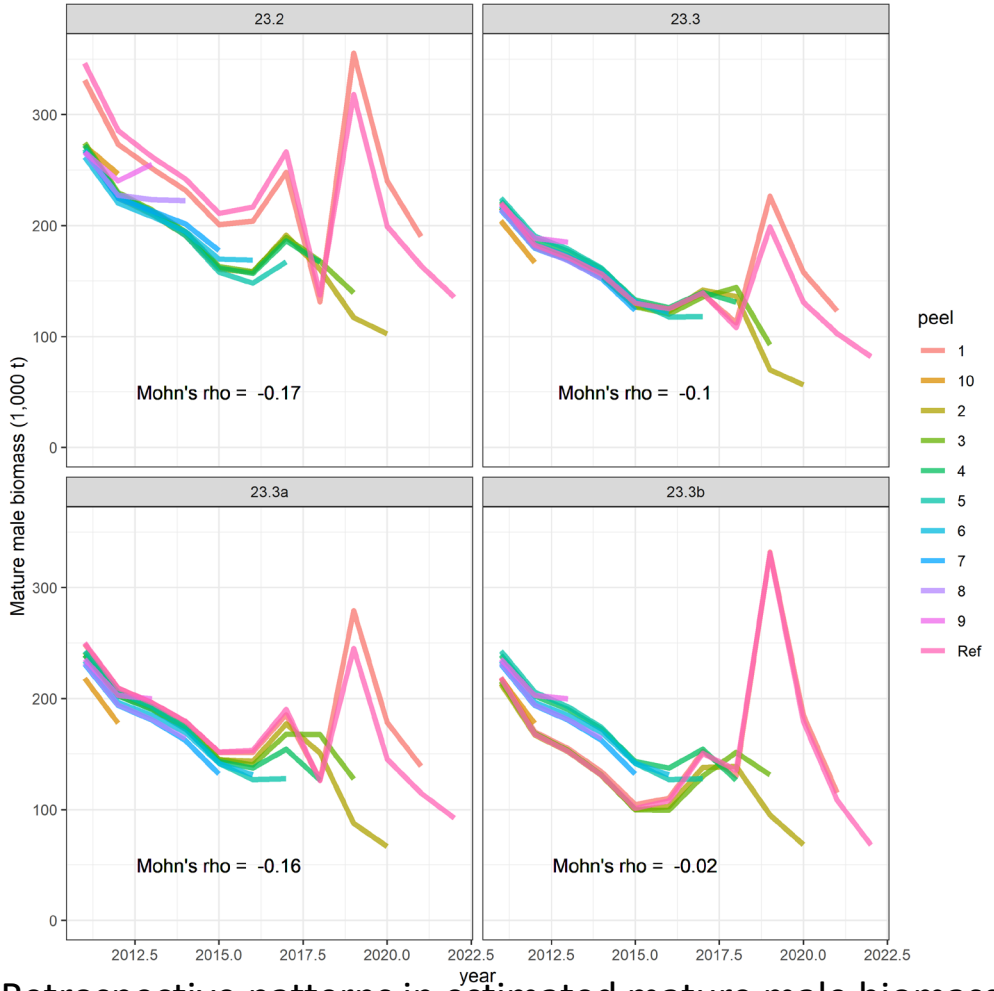
Remaining natural mortality applied before the next survey.

22.1	Last year's accepted model
23.1	Last year's model fit to this year's data
23.2	23.1 + specifying the probability of having undergone terminal molt based on survey data
23.3	23.2 + specifying survey selectivity based on the BSFRF data
23.3a	23.3 + estimating survey selectivity with the BSFRF data as priors
23.3b	23.3a + loosening the prior on natural mortality

Process	23.1	23.2	23.3	23.3a	23.3b
Sex	Both	Both	Both	Both	Both
Maturity	Single estimated ogive	Input	Input	Input	Input
BSFRF	Survey	Survey	Prior	Prior	Prior
Survey	Estimated logistic by sex and era	Estimated logistic by sex and era	Specified non-parametric	Estimated non-parametric	Estimated non-parametric
Growth	Linear estimated	Linear estimated	Linear estimated	Linear estimated	Linear estimated
Natural.M	By sex and maturity + 2018/19	By sex and maturity + 2018/19	By sex and maturity + 2018/19	By sex and maturity + 2018/19	By sex and maturity + 2018/19 + looser prior
Fishery	Logistic	Logistic	Logistic	Logistic	Logistic

MODEL CONVERGENCE

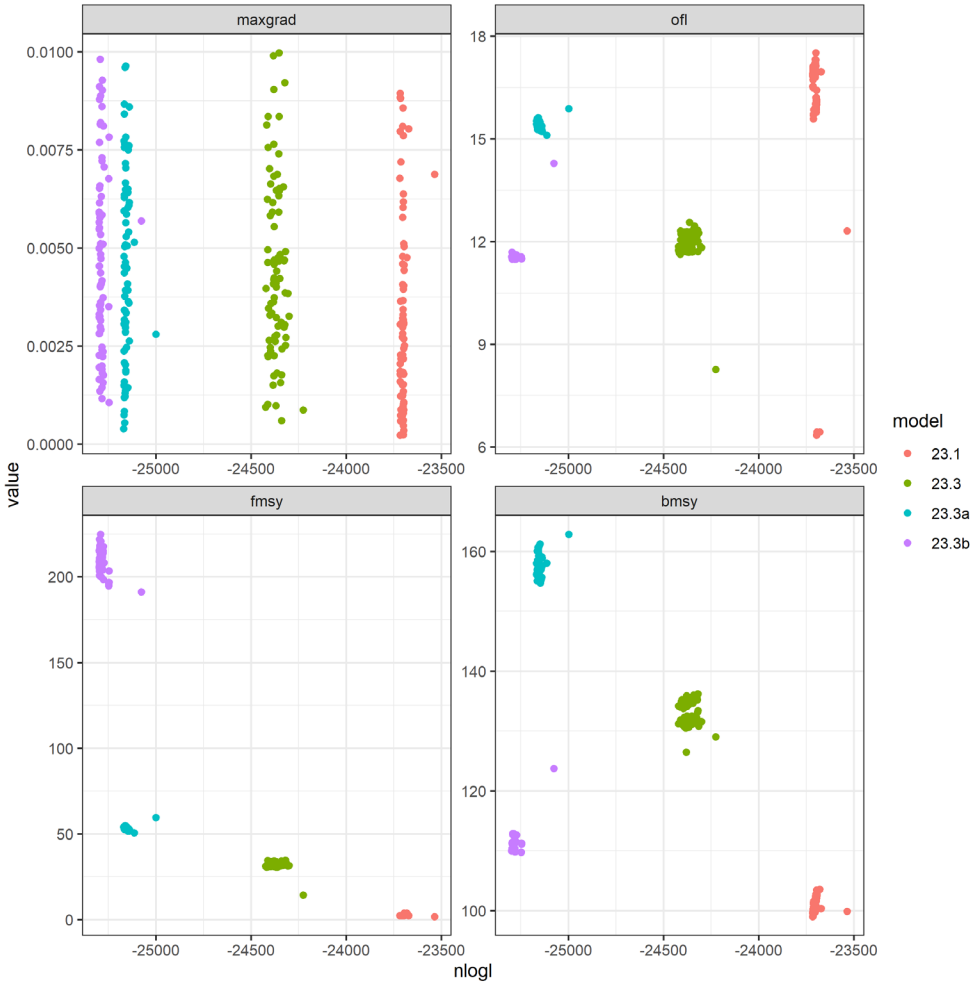
- All models produce invertible Hessian matrices and small gradients
- Retrospective patterns were acceptable, but ‘residual patterns’ were curious for some



Retrospective patterns in estimated mature male biomass for selected models.

MODEL CONVERGENCE

- All models produce invertible Hessian matrices
- Retrospective patterns were acceptable, but ‘residual patterns’ were curious for some
- Bimodality was reduced in the 23.3 series of models
- The OFL was bimodal for the status quo model with updated data.
- An issue with the jittering and Hessian matrices that I have not figured out yet…



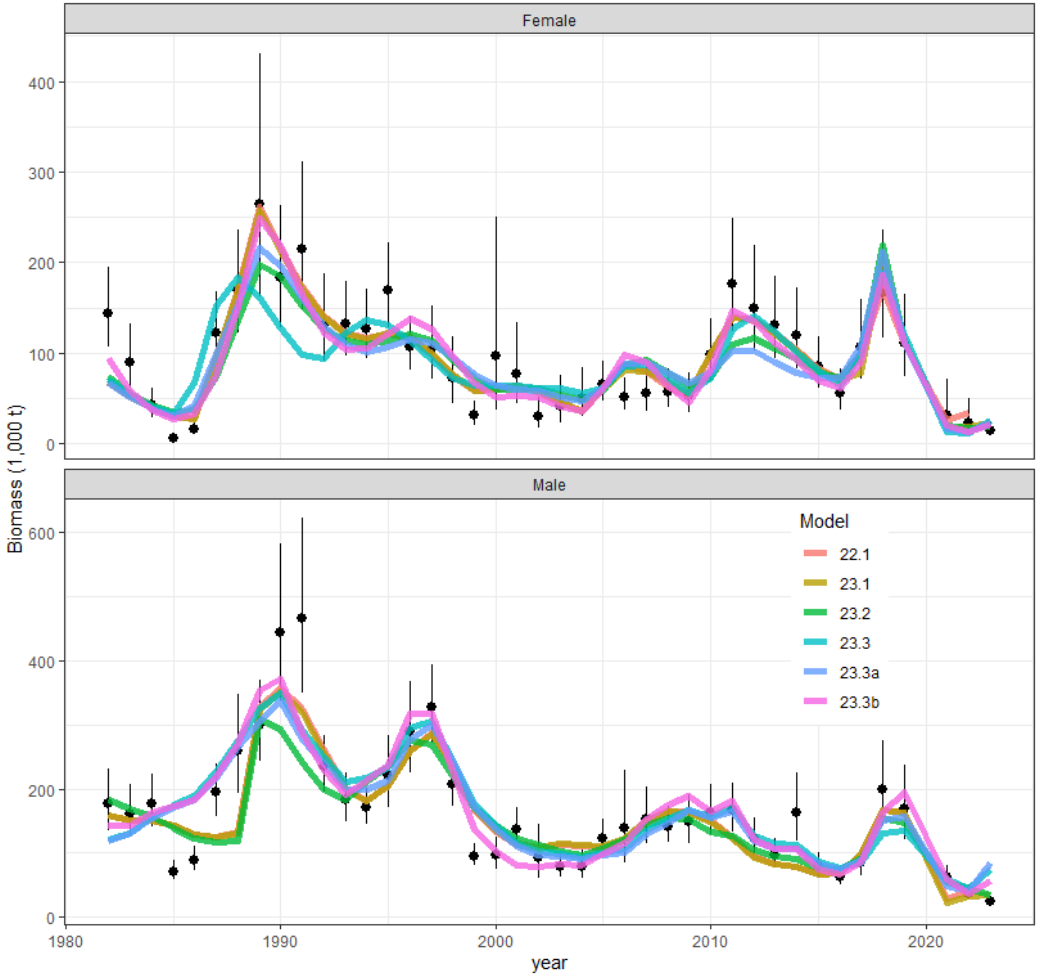
Management quantities from jittered models

MODEL FITS

- Usually keep a ‘scorecard’, but there is one preferred model
- That doesn’t mean it is perfect
  - Data weighting
  - Prior generation
  - Data sources (e.g. fit to immature or large males?)
- Haven’t recommended it before because of reference point issues, SSC gave a path around that

MODEL FITS

- Model 23.3 series had sharp uptick in final year of MMB data



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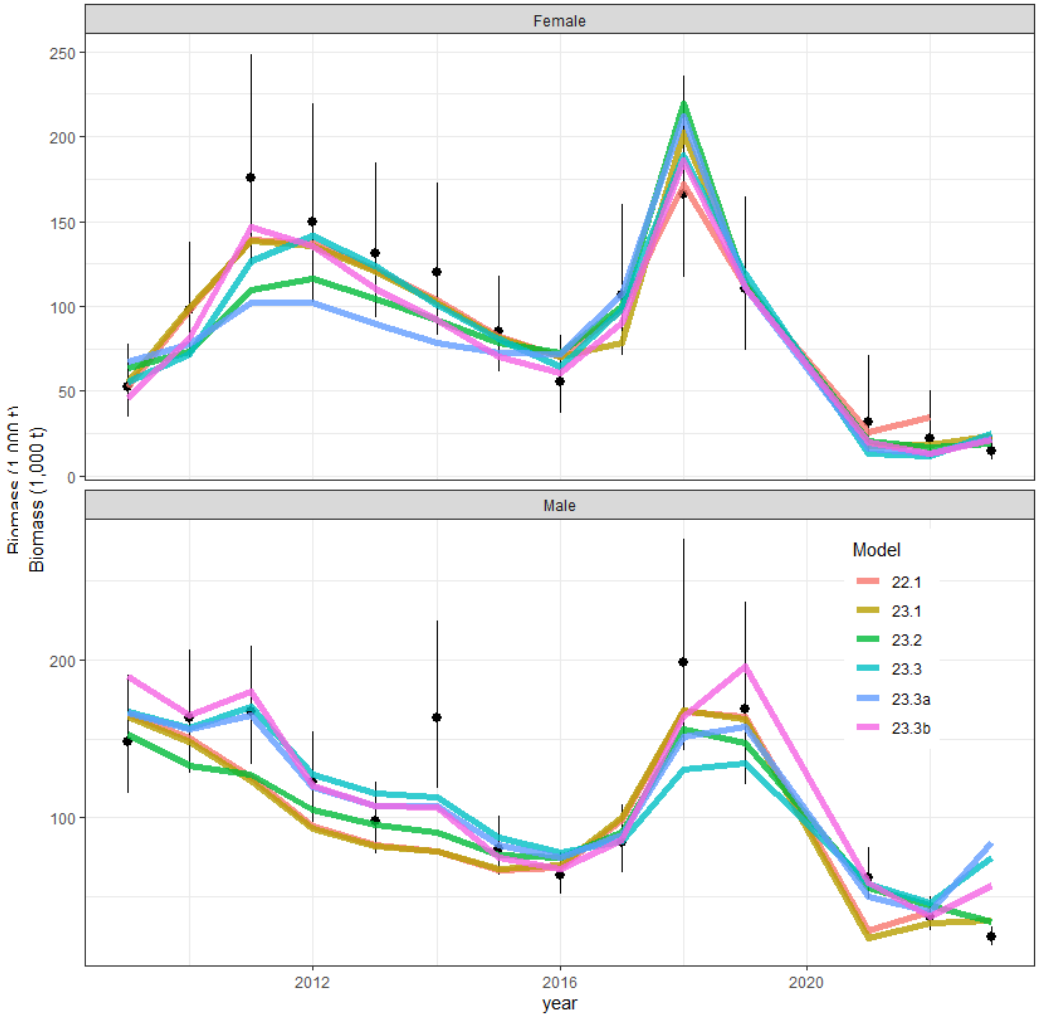

MODEL FITS

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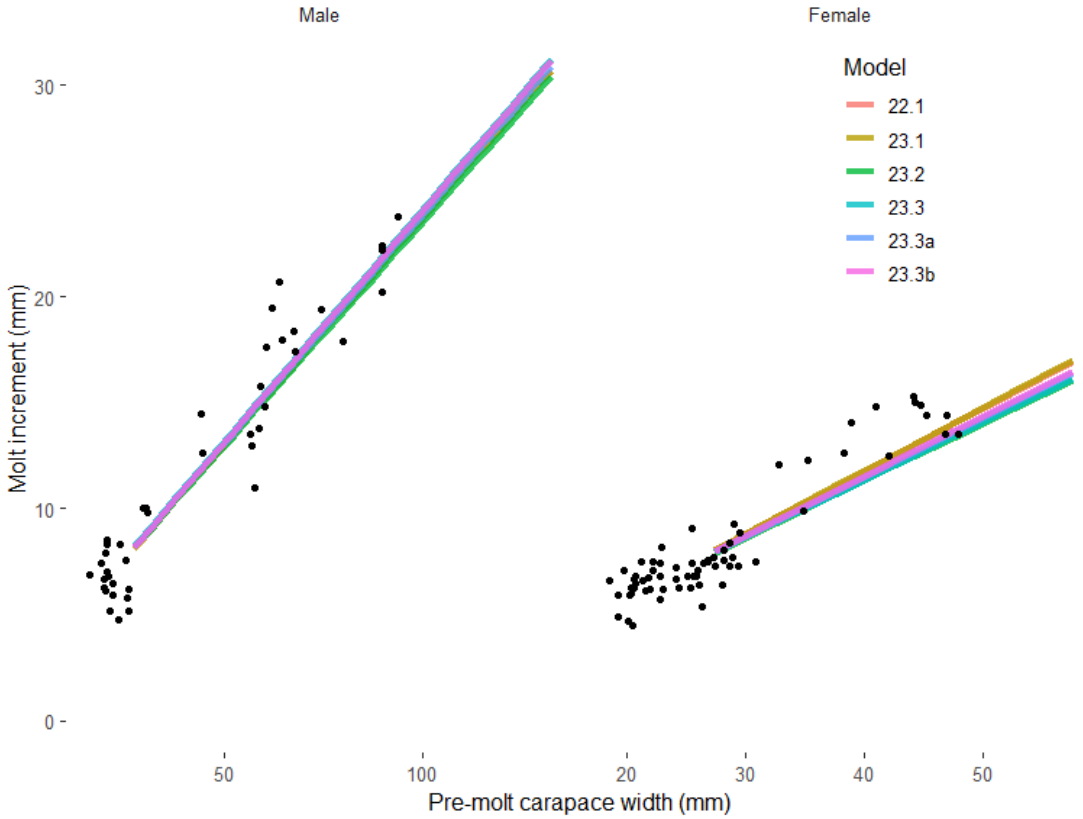

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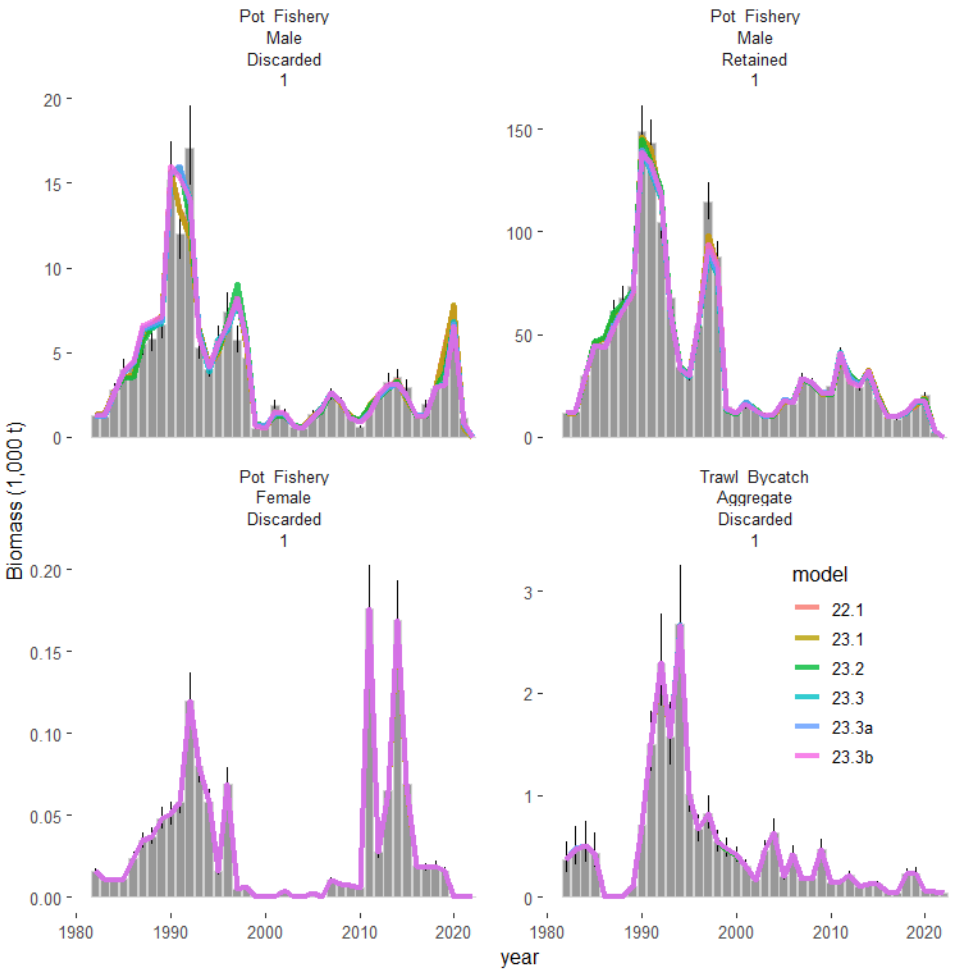

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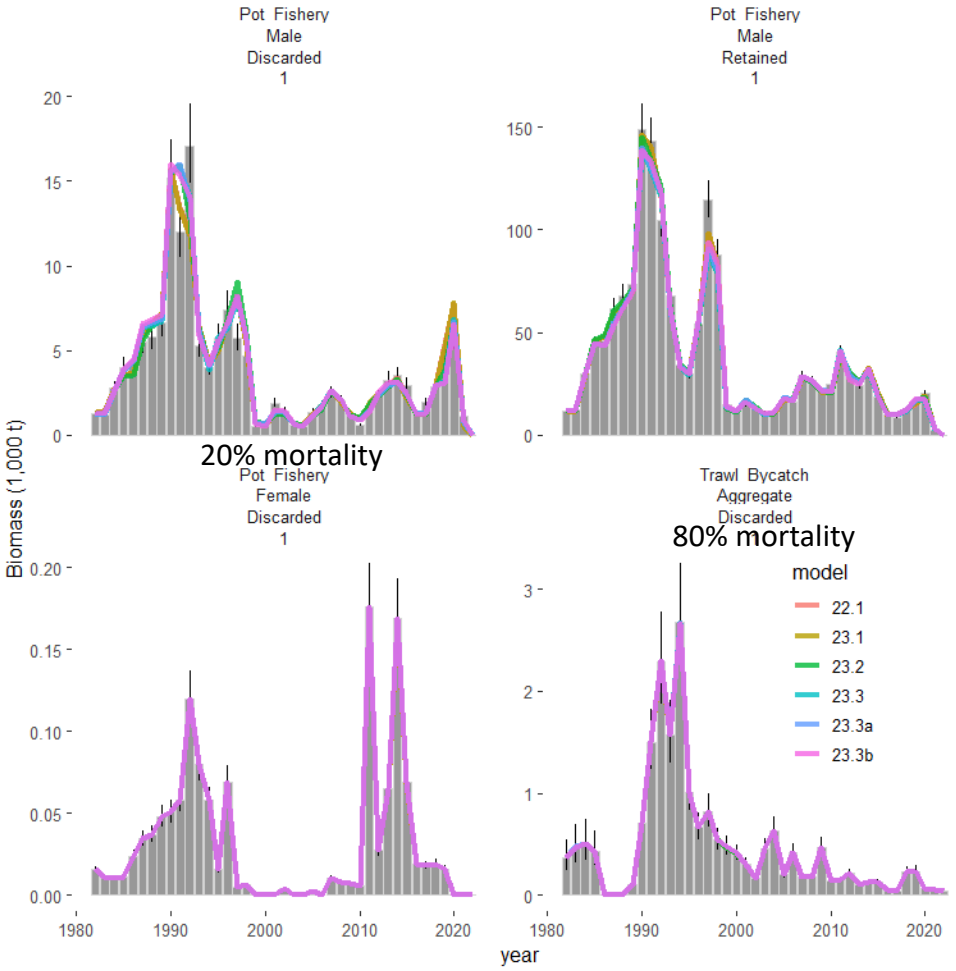

MODEL FITS

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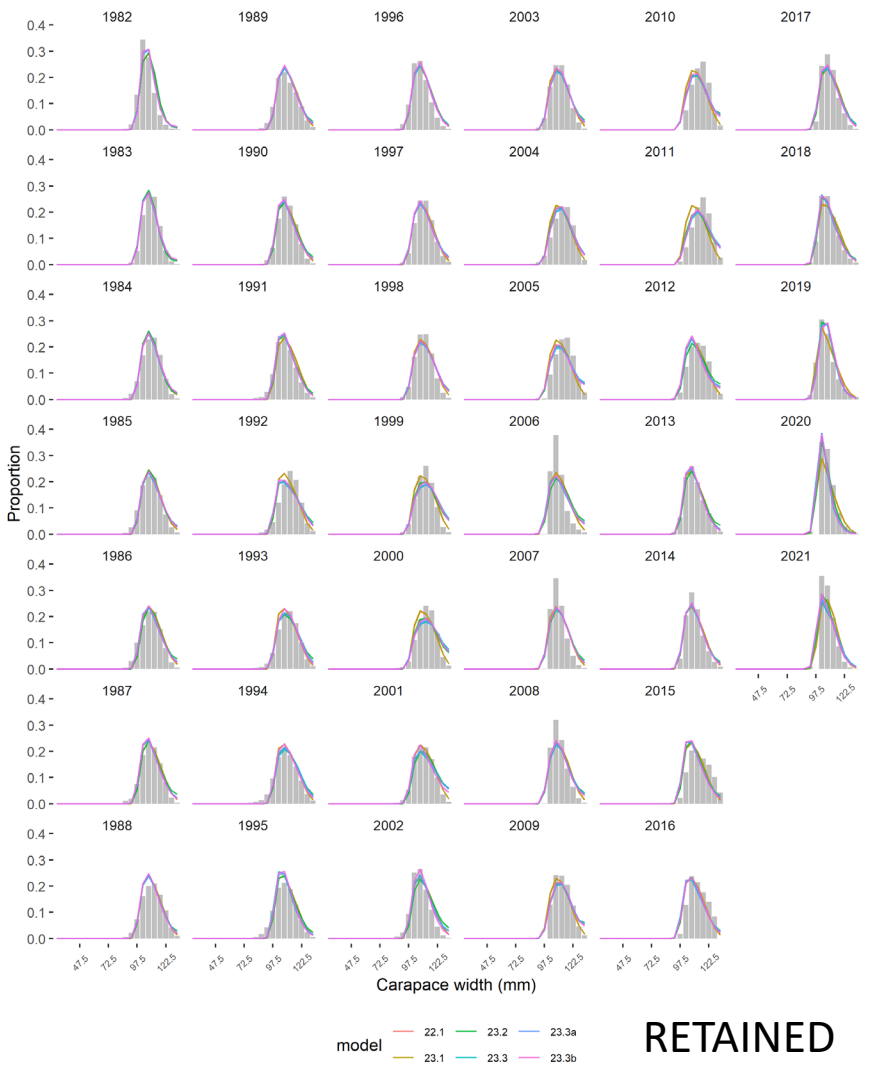
- Growth data were similarly fit
- Catch data were similarly fit
- Fishery size comps all similarly fit



RETAINED

MODEL FITS

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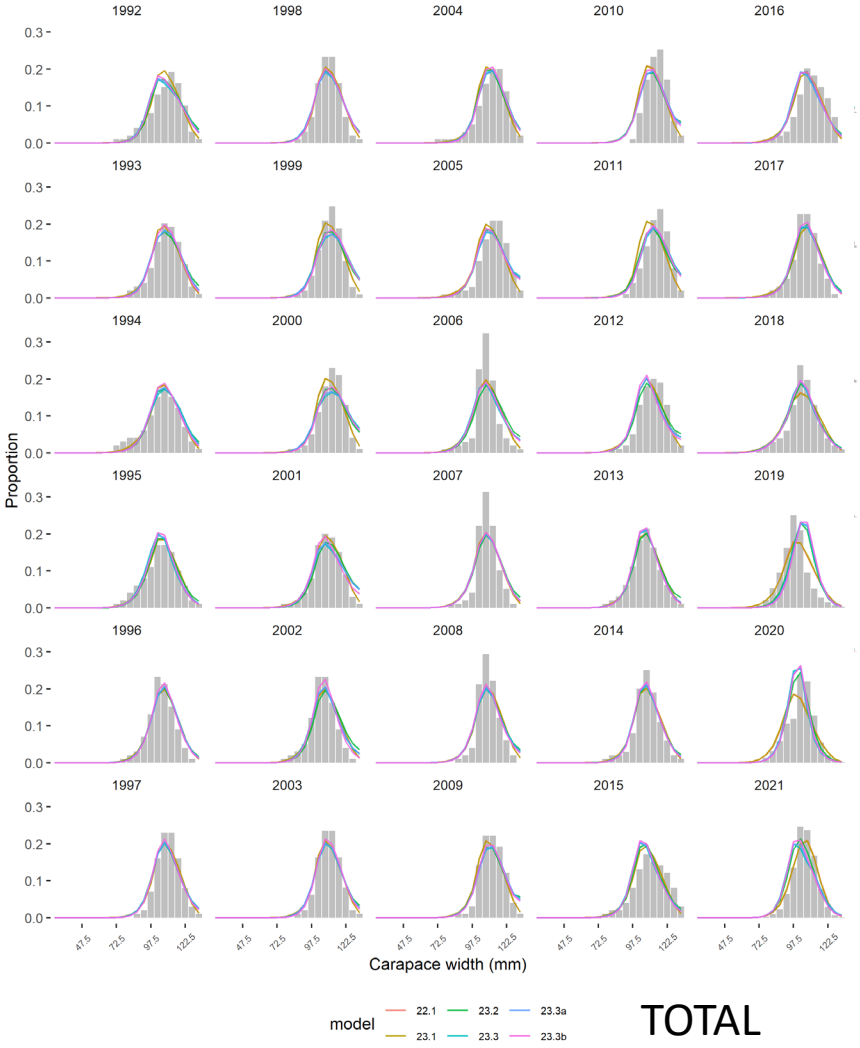

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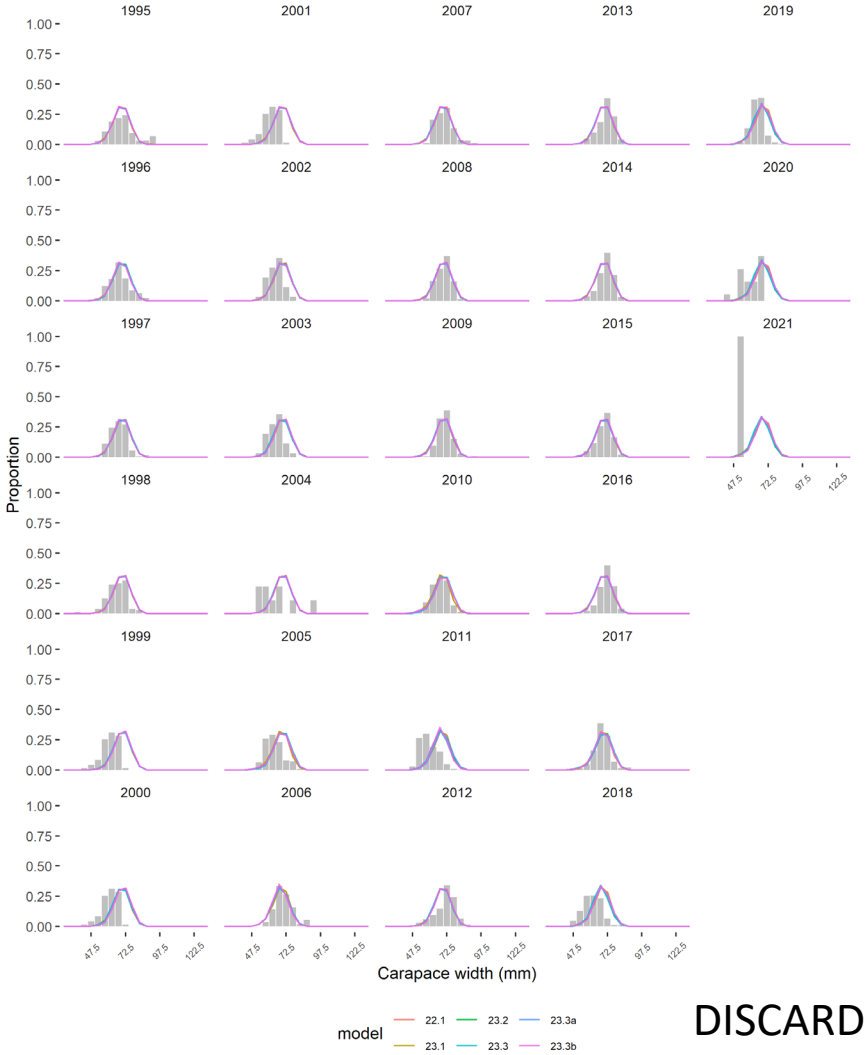

DISCARD (F)

MODEL FITS

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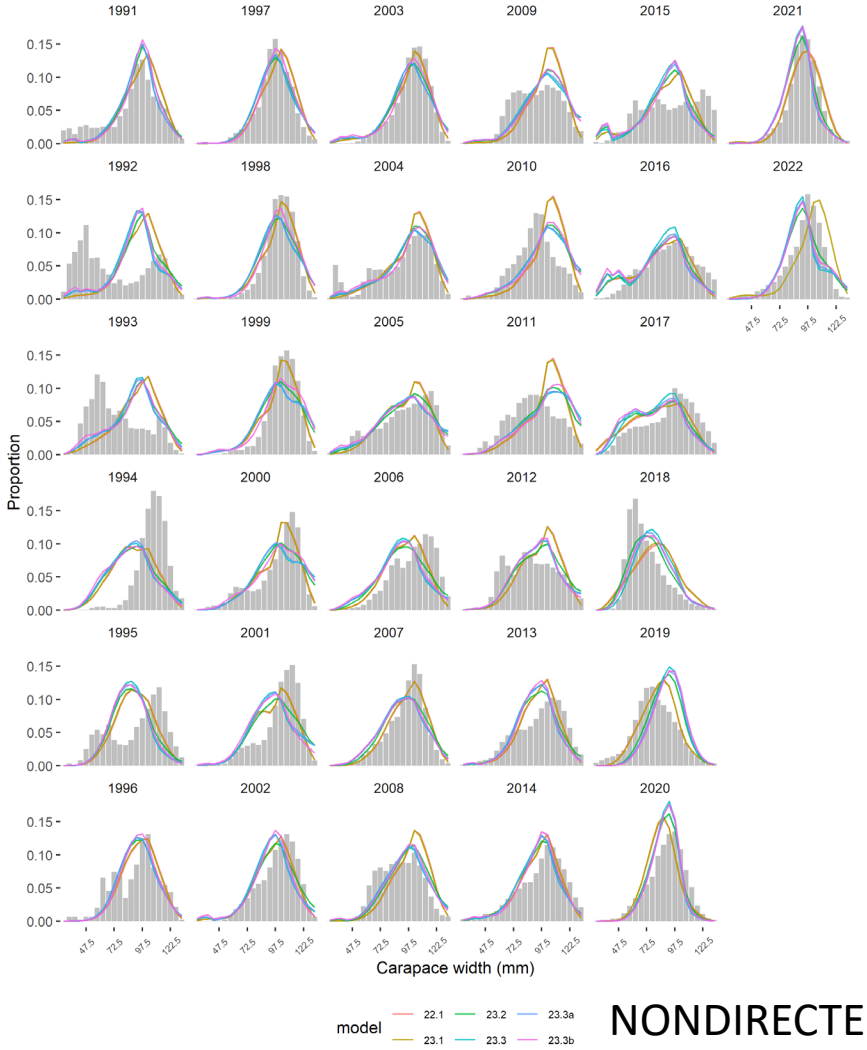

NONDIRECTED (M)

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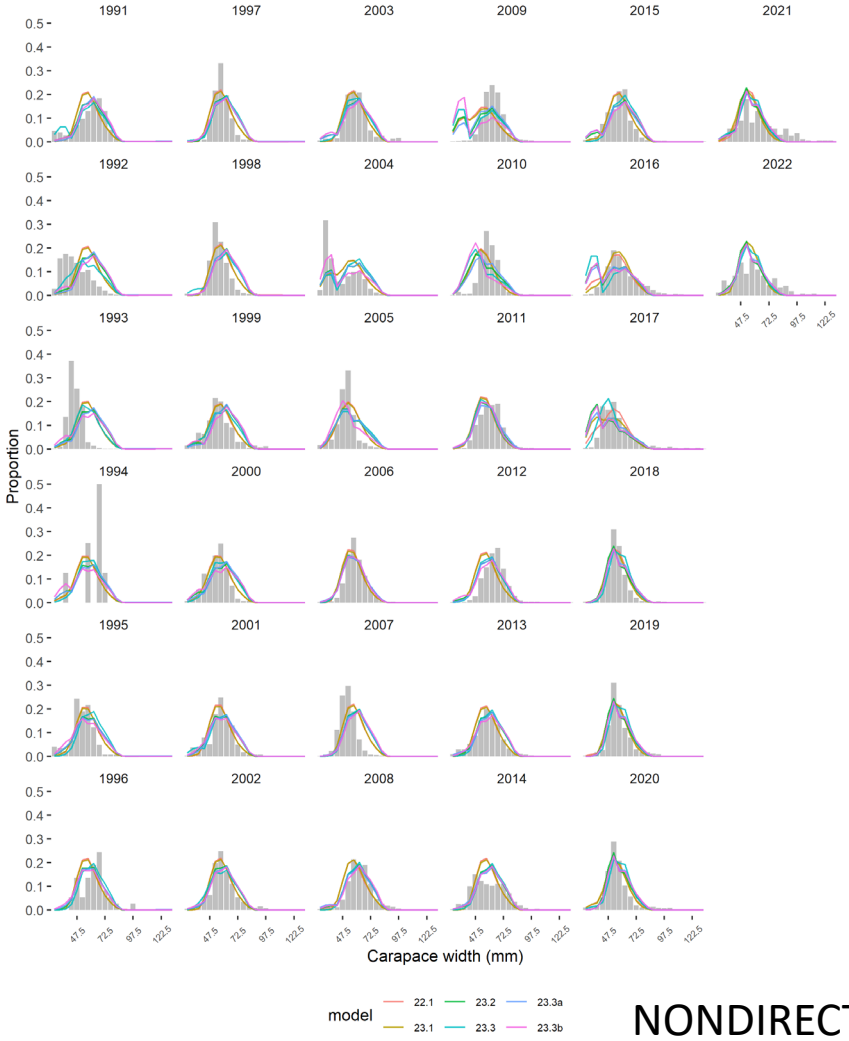
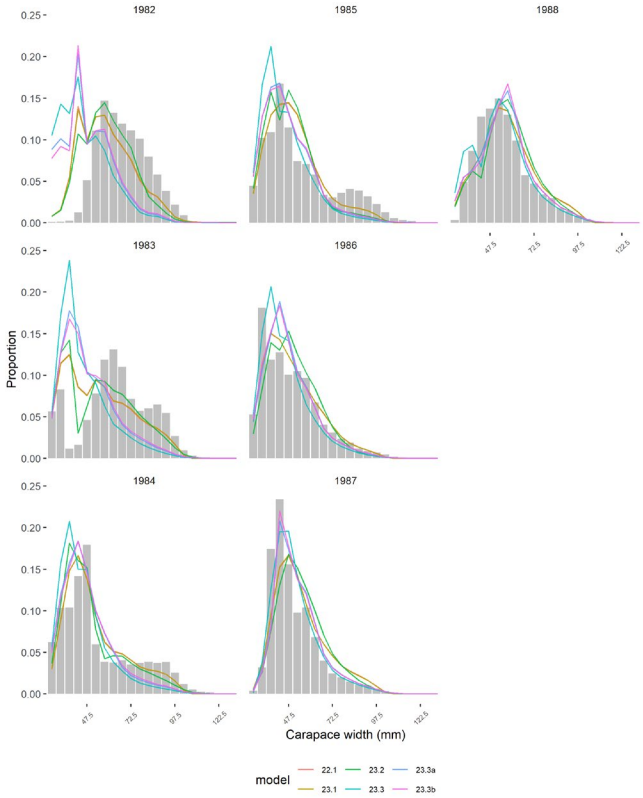


NONDIRECTED (F)

MODEL FITS

- Model 23.3 series had sharp uptick in final year of MMB data
- Growth data were similarly fit
- Catch data were similarly fit
- Fishery size comps all similarly fit
- Survey size comps were more variable



IMM SURV (M)

MODEL FITS

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- Catch data were similarly fit
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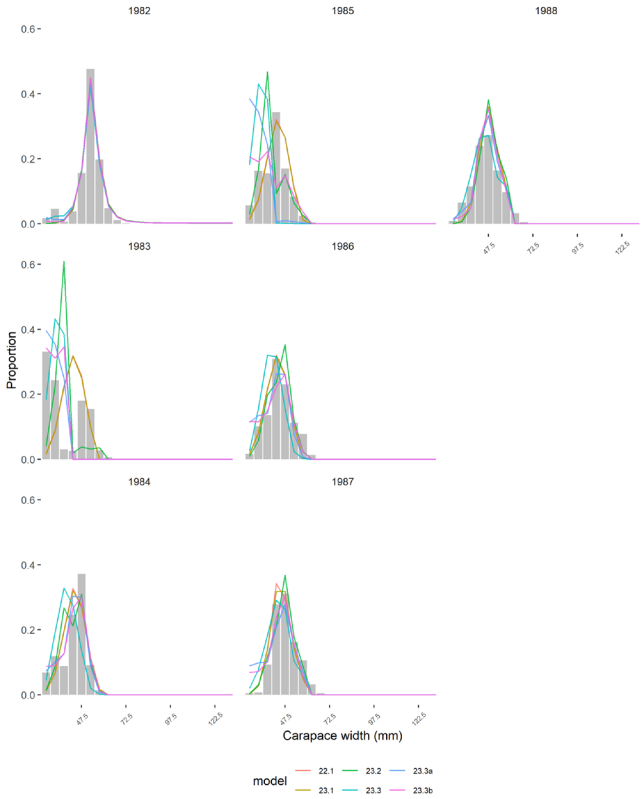
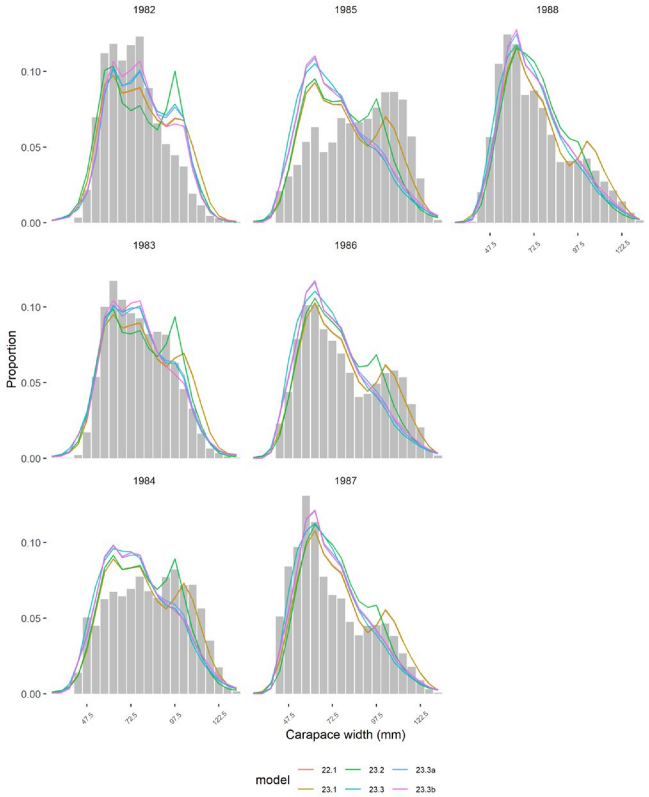


IMM SURV (F)

MODEL FITS

- Model 23.3 series had sharp uptick in final year of MMB data
- Growth data were similarly fit
- Catch data were similarly fit
- Fishery size comps all similarly fit
- Survey size comps were more variable



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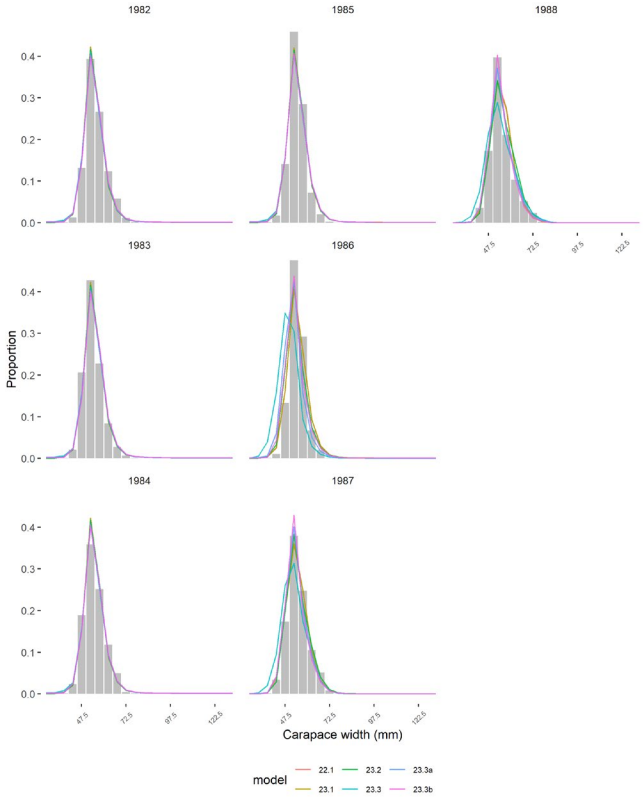

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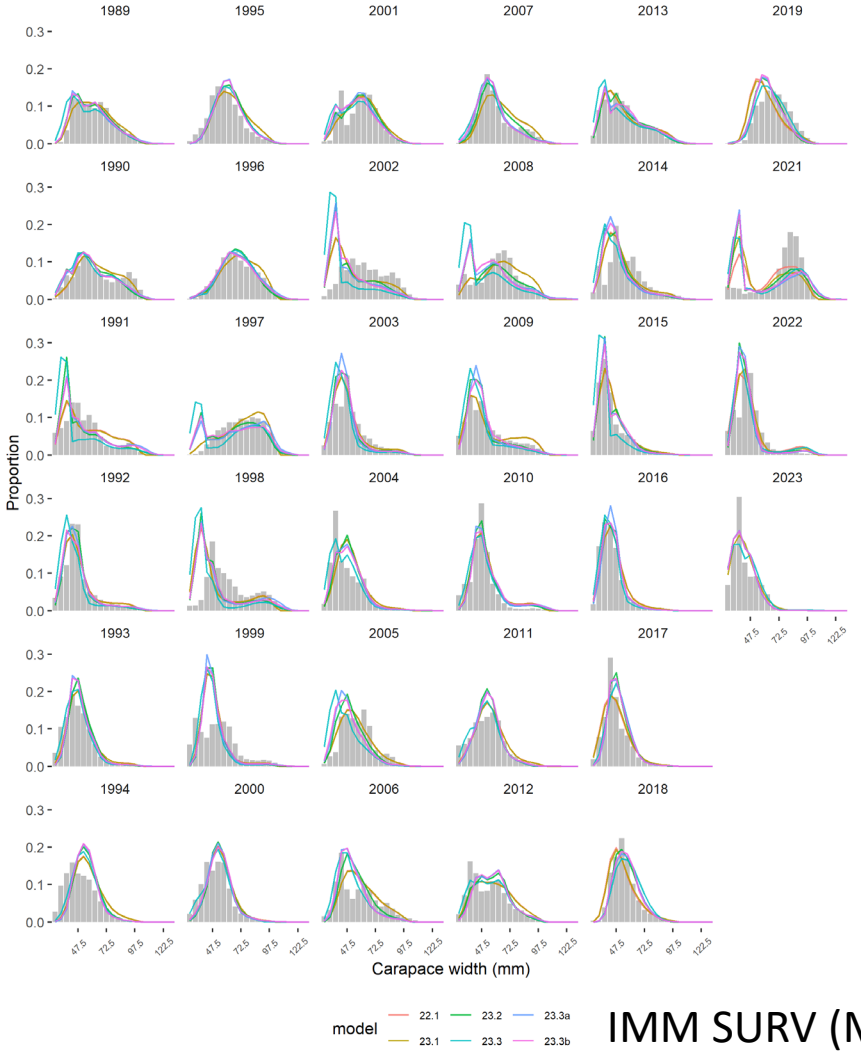

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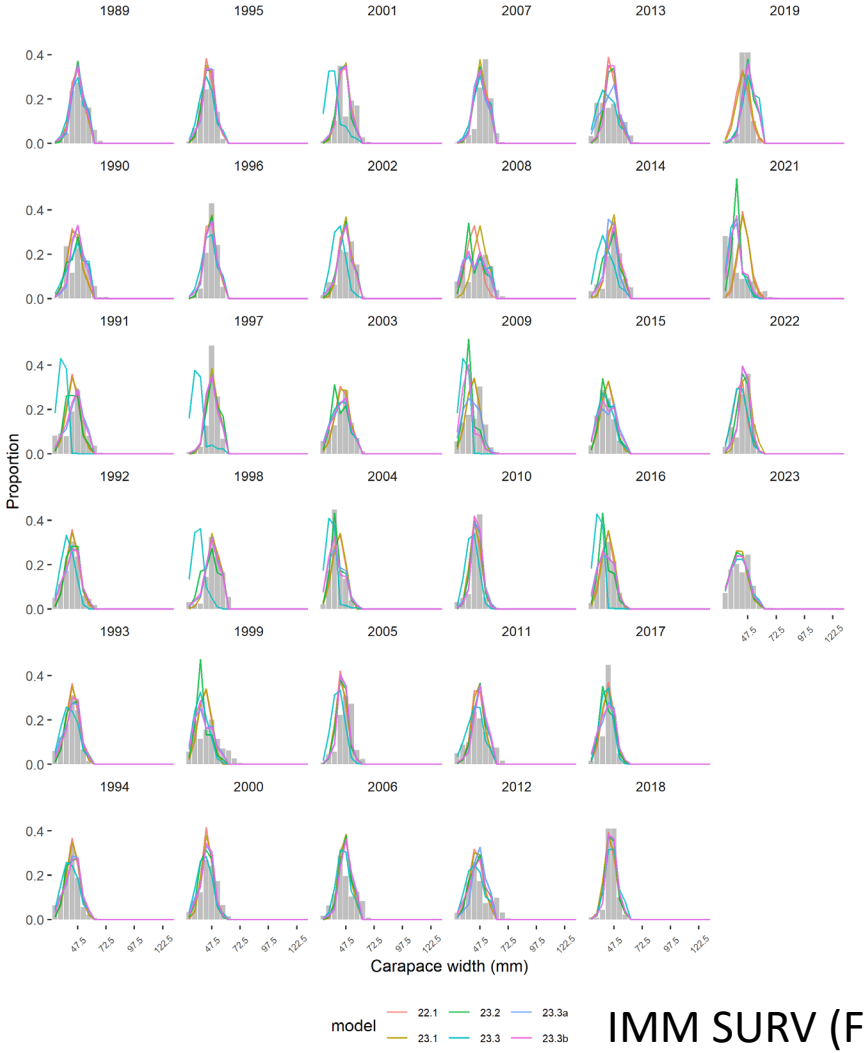

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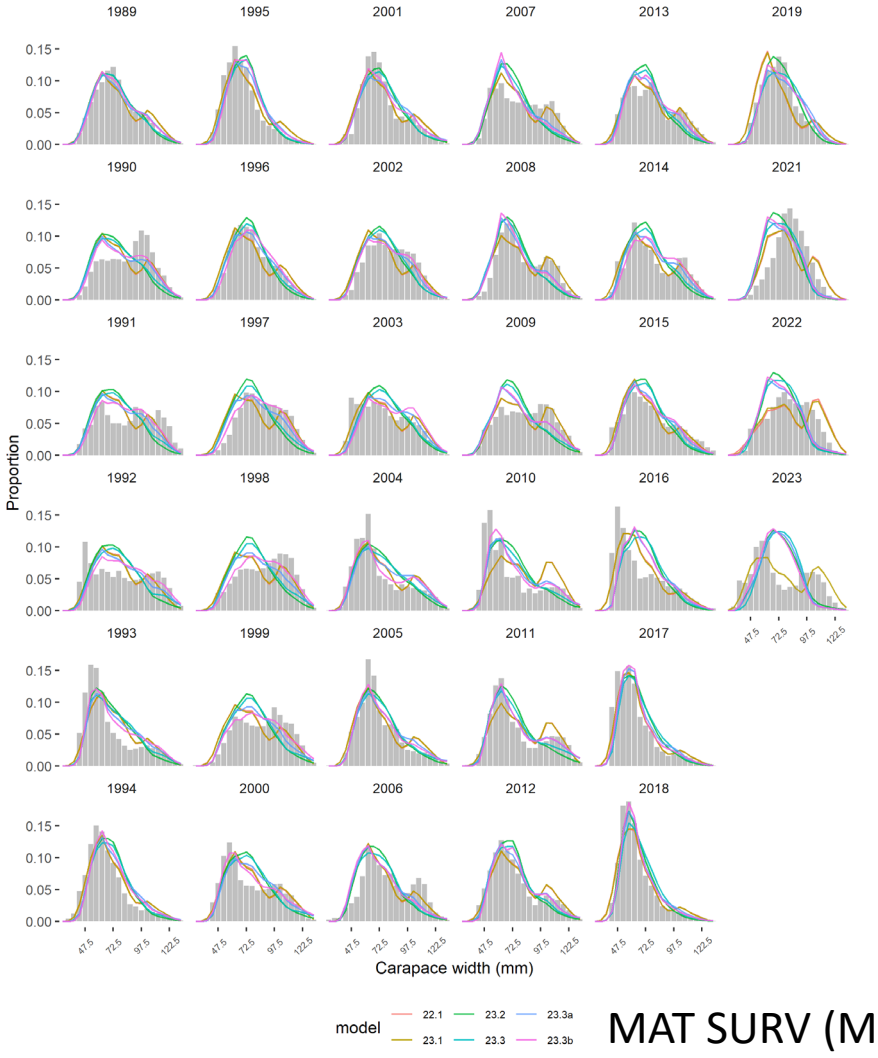

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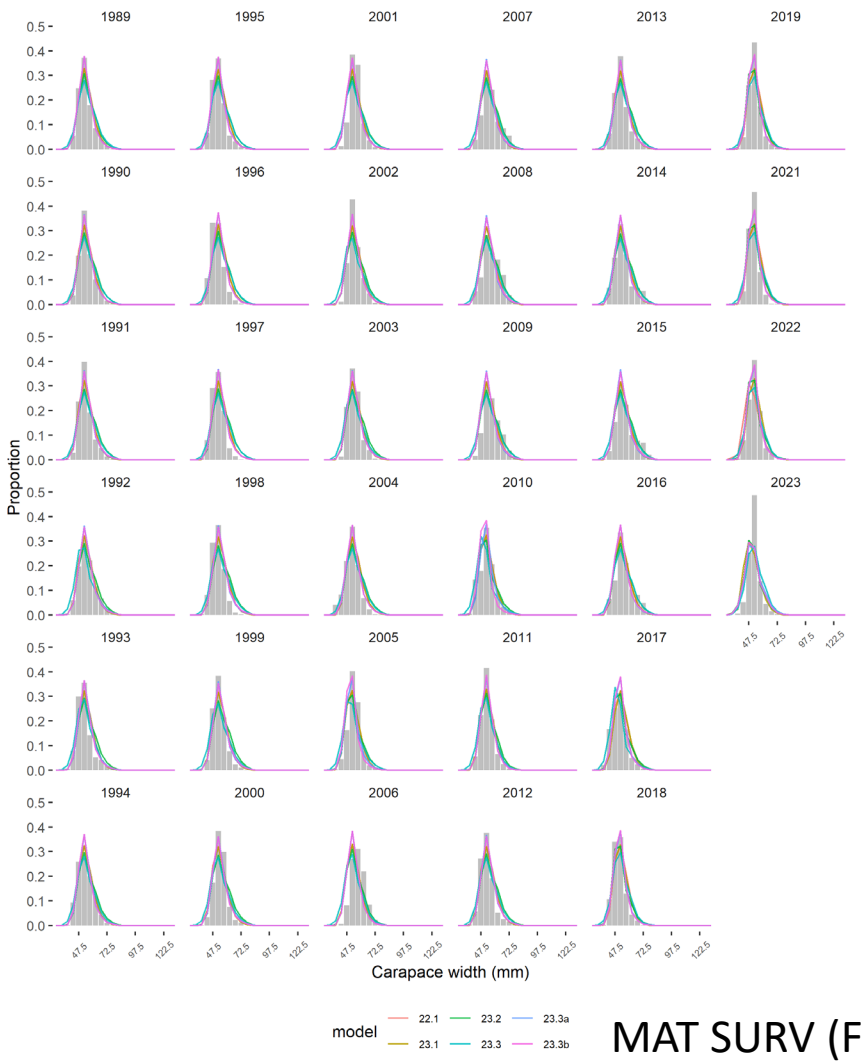
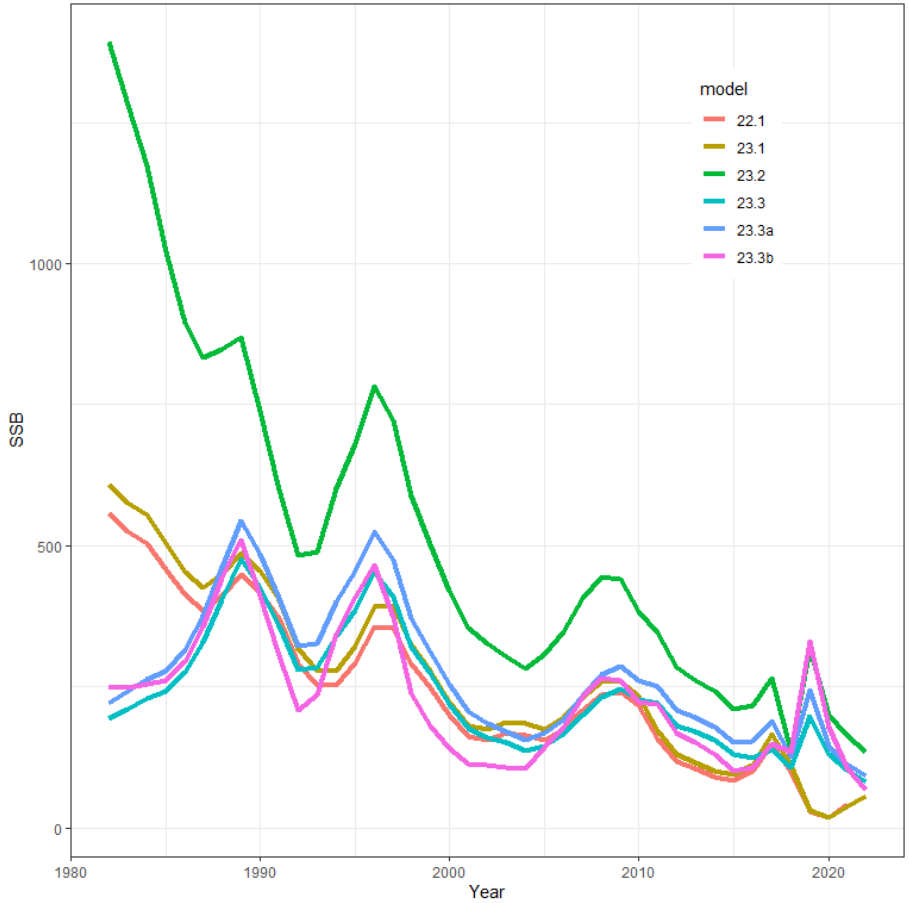


MAT SURV (F)

DERIVED AND ESTIMATED QUANTITIES

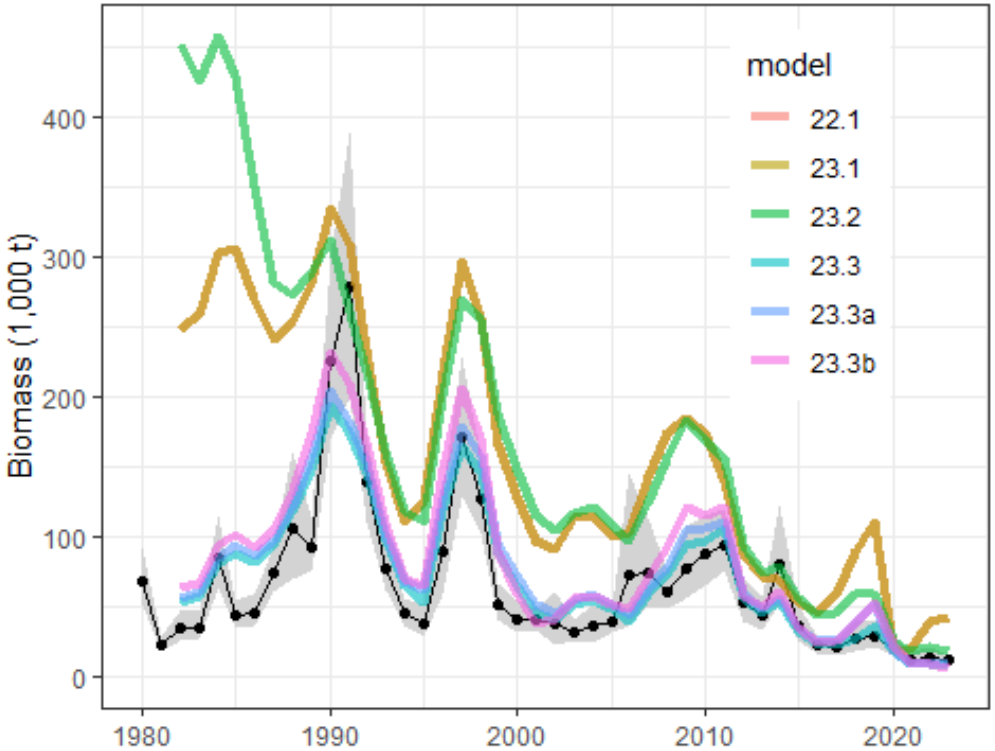
- Incorporation of terminal molt data changes interpretation of stock dynamics around the collapse
- Not concurrently including non-parametric selectivity results in larger stock sizes



Model predicted mature biomass at mating time in 1,000 tonnes.

DERIVED AND ESTIMATED QUANTITIES

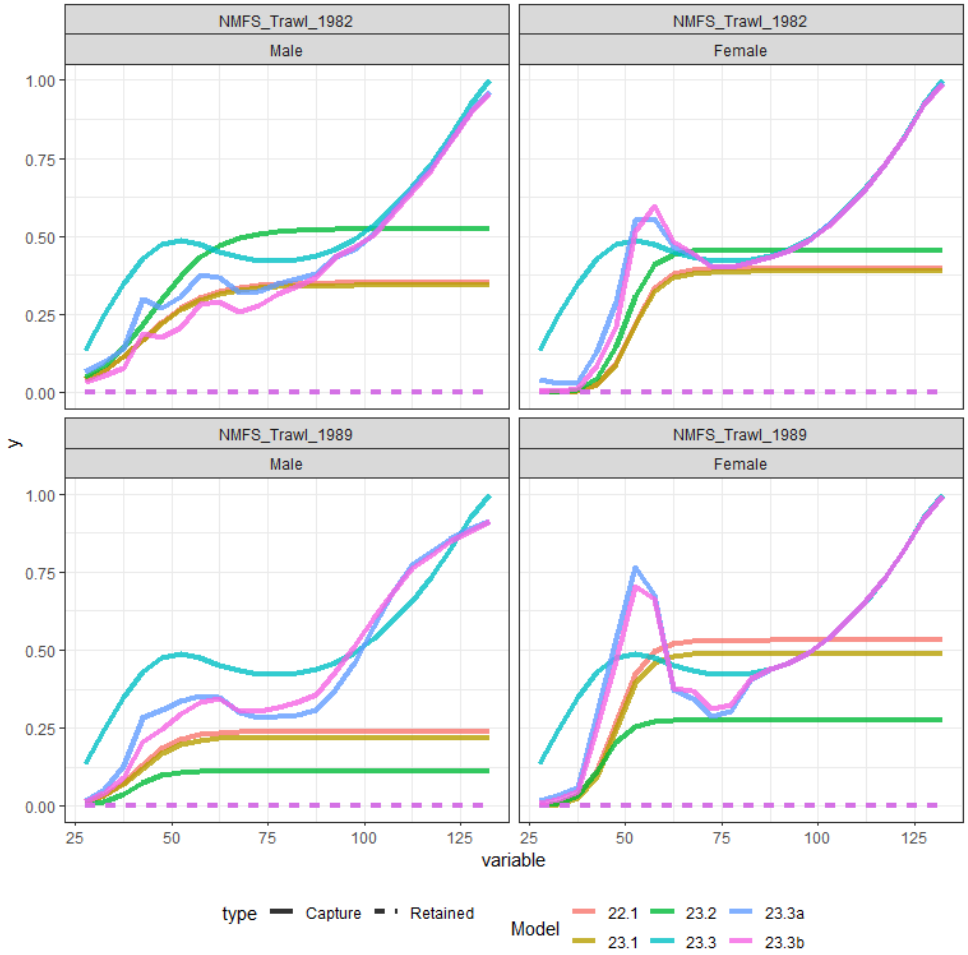
- Incorporation of terminal molt data changes interpretation of stock dynamics around the collapse
- Not concurrently including non-parametric selectivity results in larger stock sizes
- Model 23.3 series has much more similar estimates of commercial males to the survey observations
- Big difference in the early period comes from survey selectivity change in q—historical large male distribution contained in all of the survey footprints



Estimated biomass of male crab >101mm carapace width from the survey (black line and dots with gray 95th CI) and from each model in the assessment (colored lines).

DERIVED AND ESTIMATED QUANTITIES

- Difference in estimated stock size related to estimates of survey selectivity
- Female hump at small sizes somewhat strange



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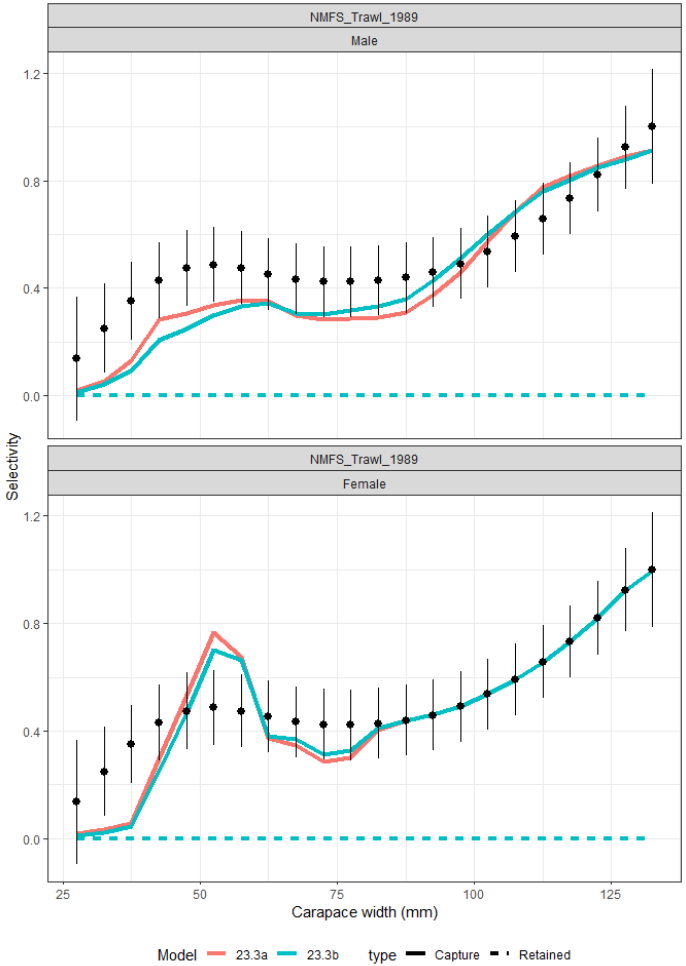
- Loosening prior on M resulted in poorer ‘fits’ to the prior at small sizes for males, better at medium sizes



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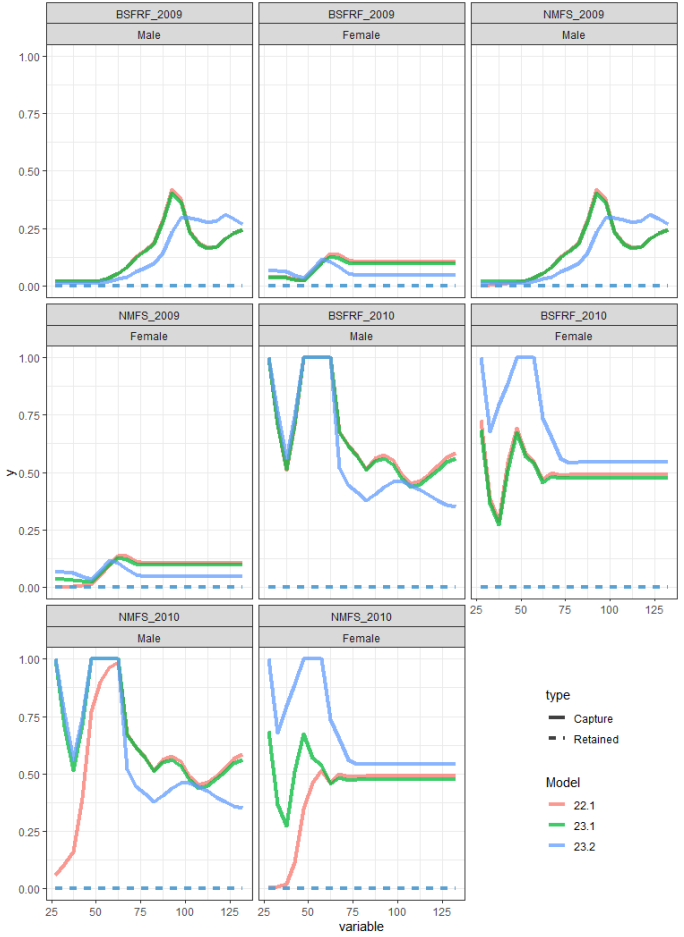
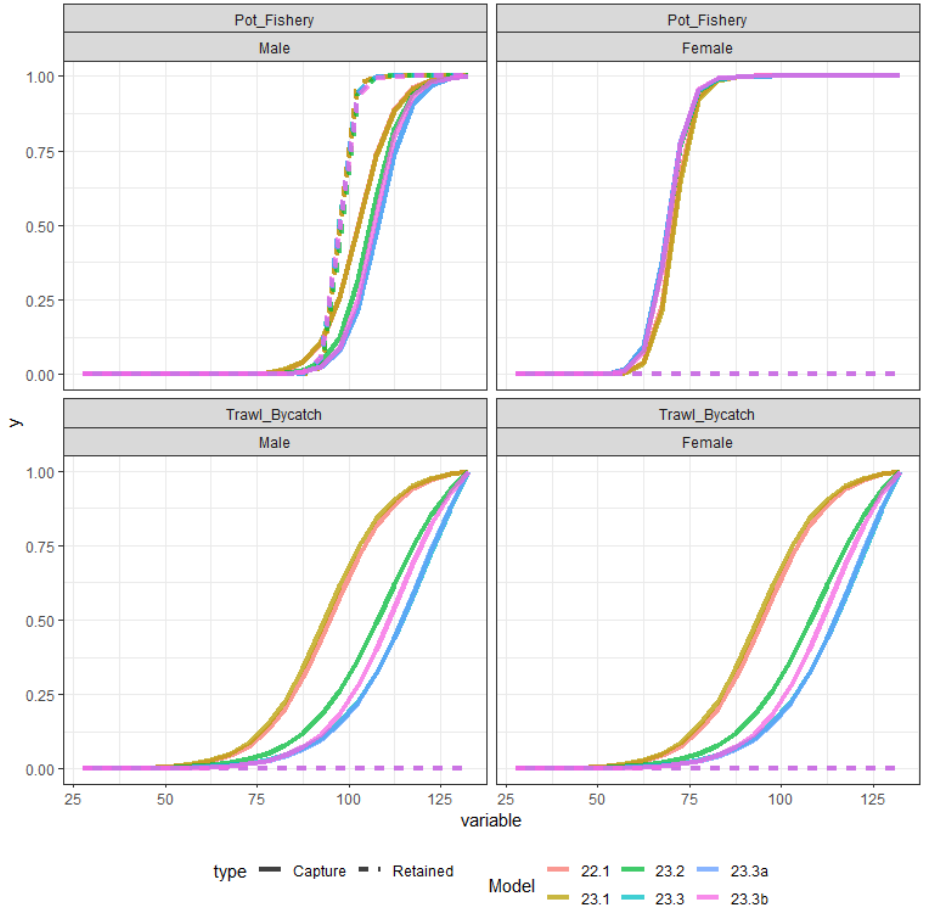


DERIVED AND ESTIMATED QUANTITIES

- Retained fishery selectivity similar across models
- Non-directed fishery selectivity shifted to the right for 23.3 series



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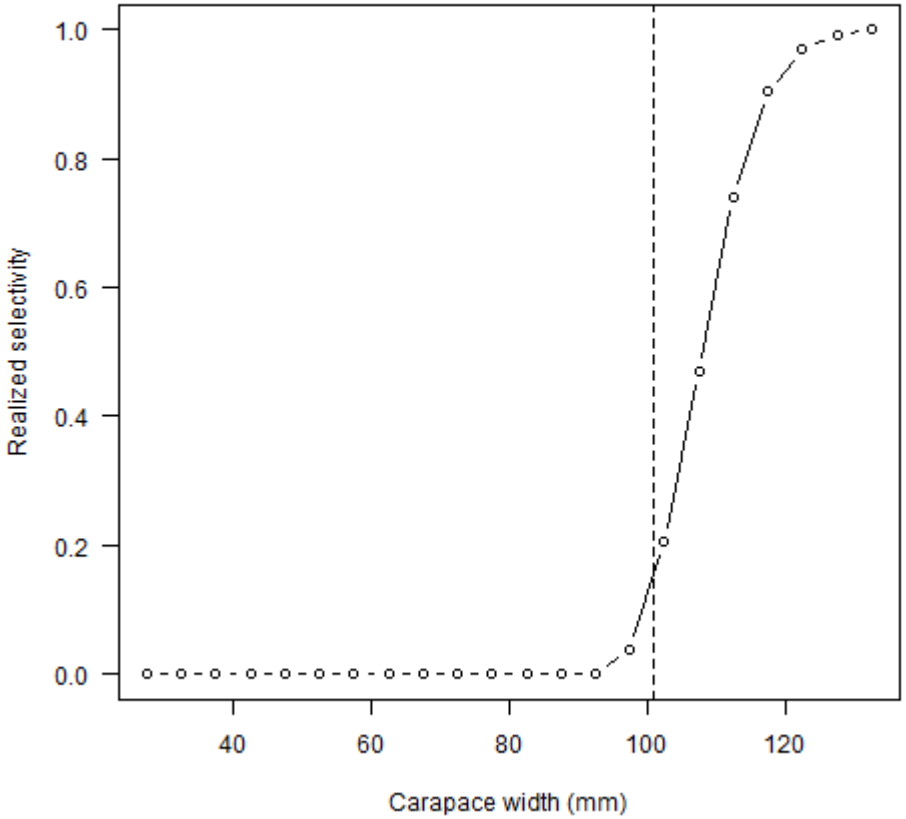
```
vul = elem_prod(sel, ret + (1.0 - ret) * xi);          ///> Vulnerability
F(h,i,j) += ft(k,h,i,j) * vul;                         ///> Fishing mort
```



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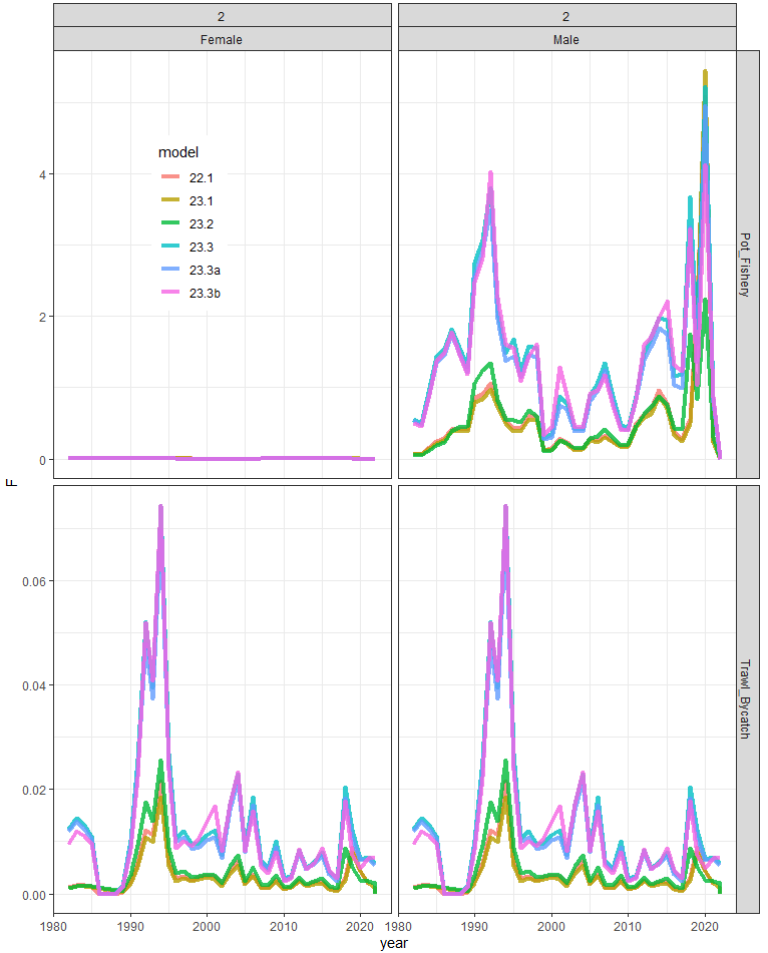

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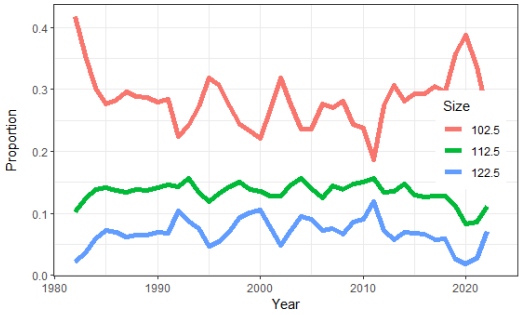
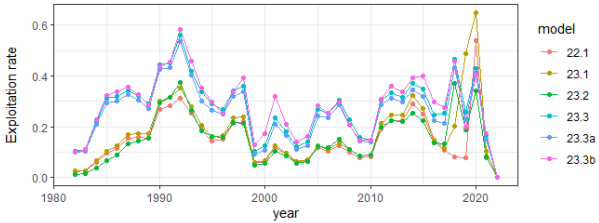
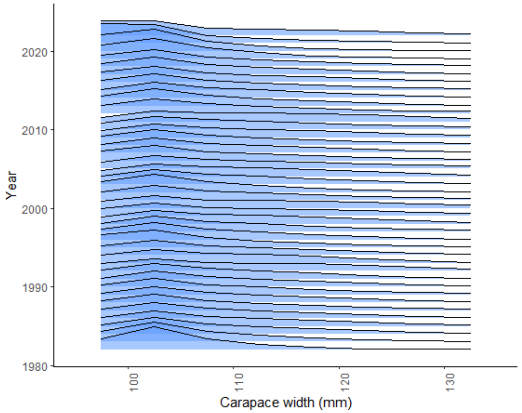
- Retained fishery selectivity similar across models
- Non-directed fishery selectivity shifted to the right for 23.3 series
- Estimated fishing mortalities in 2020 still high for most models.
- Estimated F for 23.3 series also high in early 1990s
- Calculated exploitation rates (retained catch / male>101mm) much lower than the fully-selected fishing mortalities

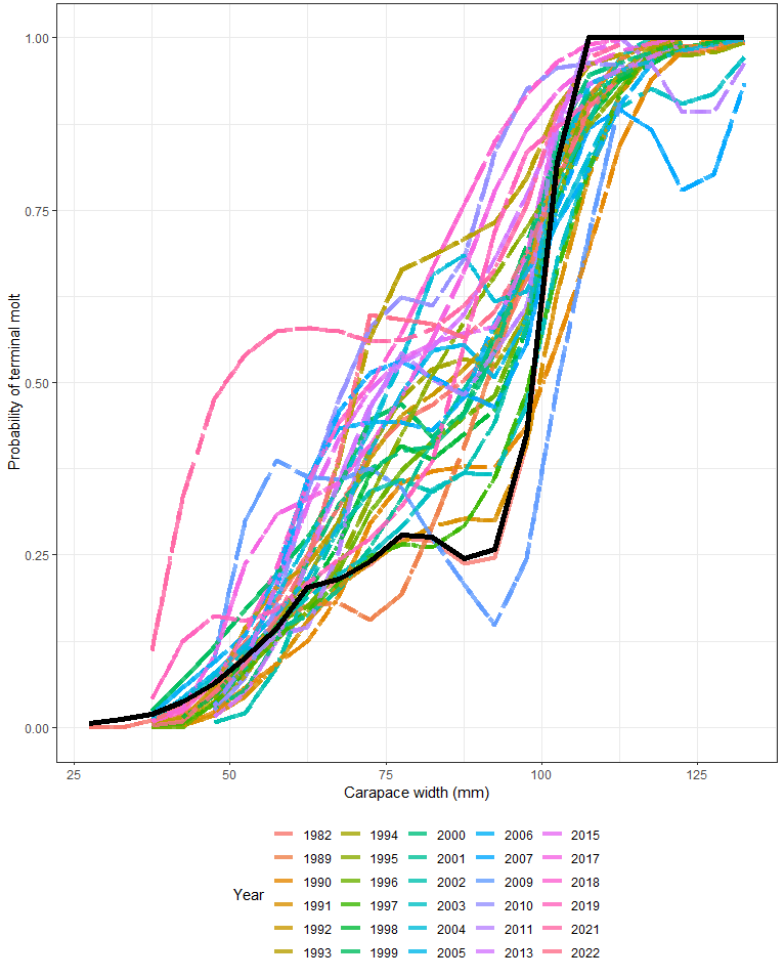






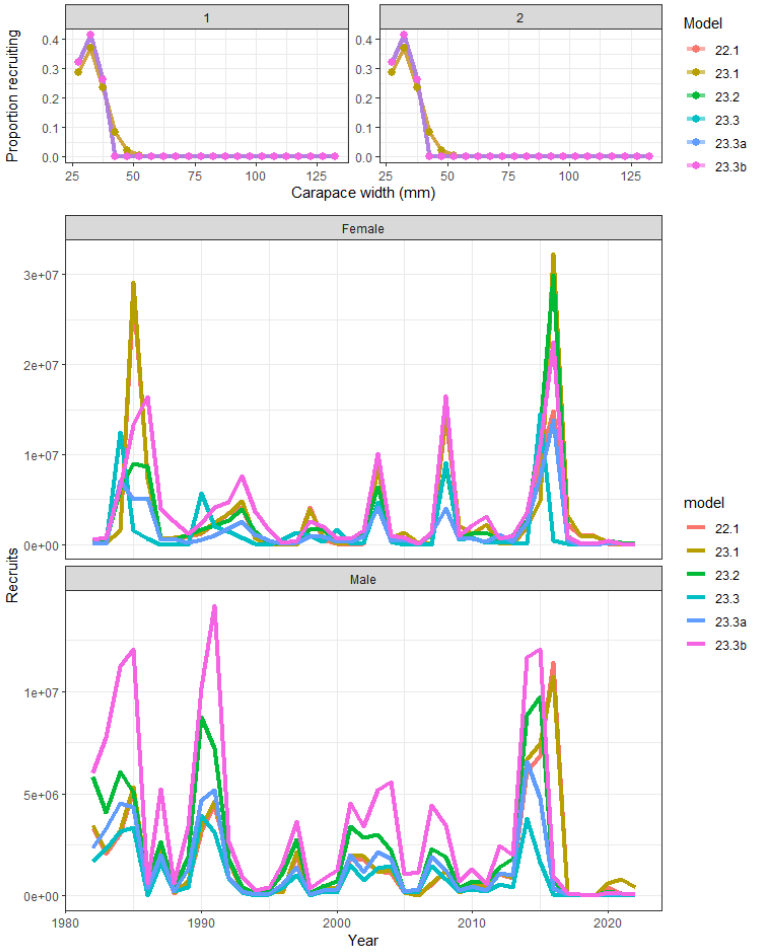
DERIVED AND ESTIMATED QUANTITIES

- Estimates probability of having undergone terminal molt still relatively low
- Why does the status quo model do this?
- The model ‘needs’ animals to continue growing because logistic selectivity that has the same catchability for medium sized animals as large animals need the medium sized animals to grow to large sizes. Given growth and M are based on informative data or priors, the way for this to happen is by reducing the probability that growth ceases.



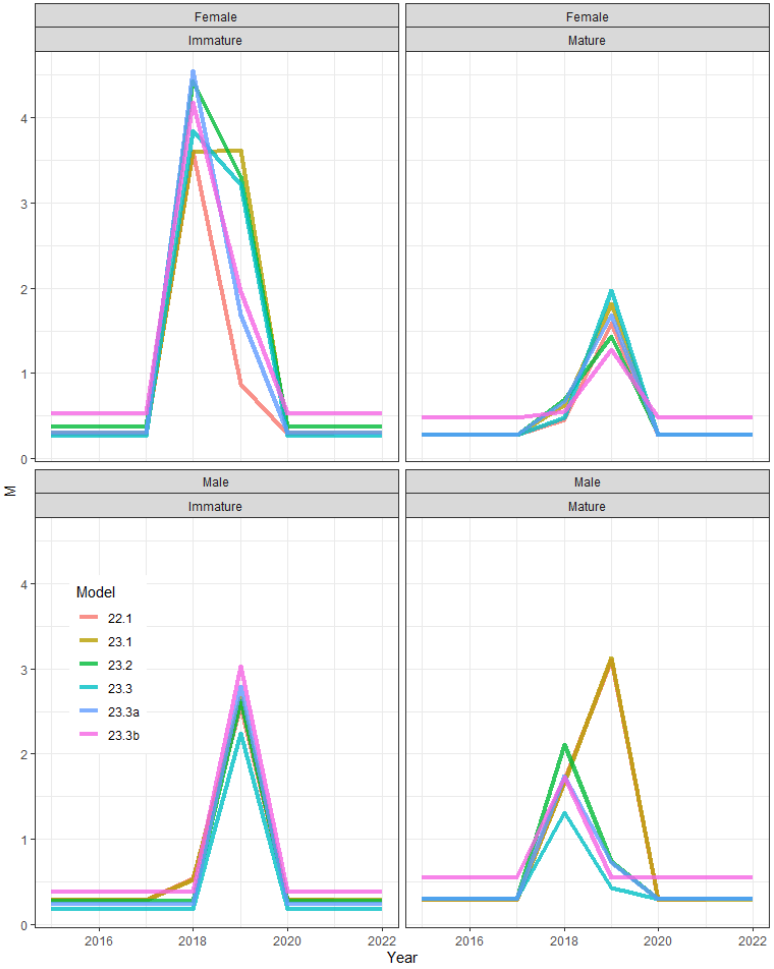
DERIVED AND ESTIMATED QUANTITIES

- Recruitment patterns are similar across models, but there is some disagreement on timing of estimates of the most recent large cohort



DERIVED AND ESTIMATED QUANTITIES

- Recruitment patterns are similar across models, but there is some disagreement on timing of estimates of the most recent large cohort
- Estimated mortality in 2018 and 2019 was highest for immature females.
- The timing of the peaks in mortality was different among models for mature males.



MODEL CONCLUSIONS

- Model 23.3 series incorporate the best available science on the biology of the stock in the most defensible ways.
- Model 23.3a and b are preferable over 23.3 because they propagate uncertainty in survey selectivity.
- Model 23.3a is preferable to 23.3b because loosening the prior on M results in a higher M than has historically been assumed and has important effects on stock dynamics.

Model 23.3a is the author-preferred model

MANAGEMENT DECISIONS

Strategy	Fishing mortality target	Biomass target	Biomass currency
Tier 3	F35%	B35%	Morphometrically mature males
Tier 4_ssc	Natural mortality	B35%	Morphometrically mature males
Tier 4_specs	Natural mortality	Average from 1982-2022	Morphometrically mature males
Tier 4_survey	Natural mortality	Average from 1982-2022	>101 mm carapace width

Tier 3

Model	MMB	B35	F35	FOFL	OFL	M	avg_rec	Status
22.1	41.21	183.15	1.50	0.32	10.32	0.28	164.02	0.23
23.1	56.41	189.24	1.60	0.30	8.58	0.29	169.90	0.30
23.2	135.43	132.46	71.89	30.14	37.10	0.29	222.75	1.02
23.3	81.96	130.98	33.47	10.49	12.12	0.29	91.92	0.63
23.3a	92.39	155.91	53.25	14.96	15.44	0.29	141.66	0.59
23.3b	68.15	110.01	205.67	37.49	11.56	0.55	351.66	0.62

Tier 4_ssc

Model	MMB	BMSY	FMSY	FOFL	OFL	M	avg_rec	Status
23.1	56.41	189.24	0.29	0.06	2.10	0.29	169.90	0.30
23.2	135.43	132.46	0.29	0.21	2.42	0.29	222.75	1.02
23.3	81.96	130.98	0.29	0.12	0.59	0.29	91.92	0.63
23.3a	92.39	155.91	0.29	0.11	0.63	0.29	141.66	0.59
23.3b	68.15	110.01	0.55	0.16	0.52	0.55	351.66	0.62

Tier 4_specs

Model	MMB	BMSY	FMSY	FOFL	OFL	M	avg_rec	Status
23.1	56.41	267.41	0.29	0.00	0.10	0.29	169.90	0.21
23.2	135.43	519.67	0.29	0.00	0.05	0.29	222.75	0.26
23.3	81.96	236.84	0.29	0.05	0.29	0.29	91.92	0.35
23.3a	92.39	273.83	0.29	0.05	0.31	0.29	141.66	0.34
23.3b	68.15	232.32	0.55	0.00	0.03	0.55	351.66	0.29

Tier 4_survey

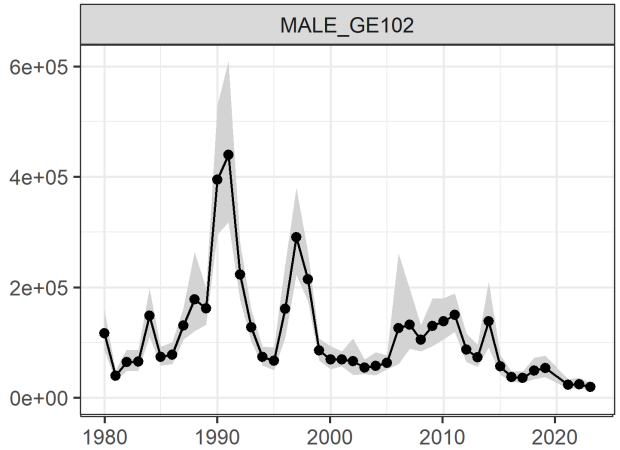
Year	BMSY	Males_com	Status	FOFL	OFL	Years	M
2023/2024	59.64	9.996	0.1676	0	0	1982-2022	0.27

MANAGEMENT DECISIONS

Strategy	PRO	CON
Tier 3	SPR-based theory is satisfying	Allows for the complete removal of large males when morphometric maturity + SPR35% is used
Tier 4_ssc	M = FMSY reduces the maximum fishing mortality on the stock compared to Tier 3	• B35% can still only be reached by removing all of the large males. • Assumes functional equivalence between small and large mature males. • Time-varying terminal molt at size • The stock would not be overfished under B35%. • The interaction of M and fishery selectivity
Tier 4_specs	• M = FMSY reduces the maximum fishing mortality on the stock compared to Tier 3 • More inline with the State strategy	Average biomass is not particularly satisfying
Tier 4_survey	Very simple	Ignores a large amount of information

Model	MMB	BMSY	FMSY	FOFL	OFL	M	avg_rec	Status
Tier 3	92.39	155.91	53.25	14.96	15.44	0.29	141.66	0.59
Tier 4_ssc	92.39	155.91	0.29	0.11	0.63	0.29	141.66	0.59
Tier 4_spc	92.39	273.83	0.29	0.05	0.31	0.29	141.66	0.34
Tier 4_srv	9.99	59.64	0.29	0.00	0.00	0.27	141.66	0.17

- Not a large difference between Tier 4 rules currently.
- Biomass reference points should protect density of large males.
- If functional maturity is true, ignoring it would be problematic.
- The probability of terminally molting may be affected by the density of large males.



Another path forward

- Change the currency to something closer to exploitable males (BBRKC for precedent).
- Identify some fraction of that currency to be left behind.
- Things to potentially consider:
  - how long they live after maturity
  - Shell condition progressions
  - Opportunities to mate
  - Measures of female reproduction—sperm reserves?
- This would require some changes to GMACS