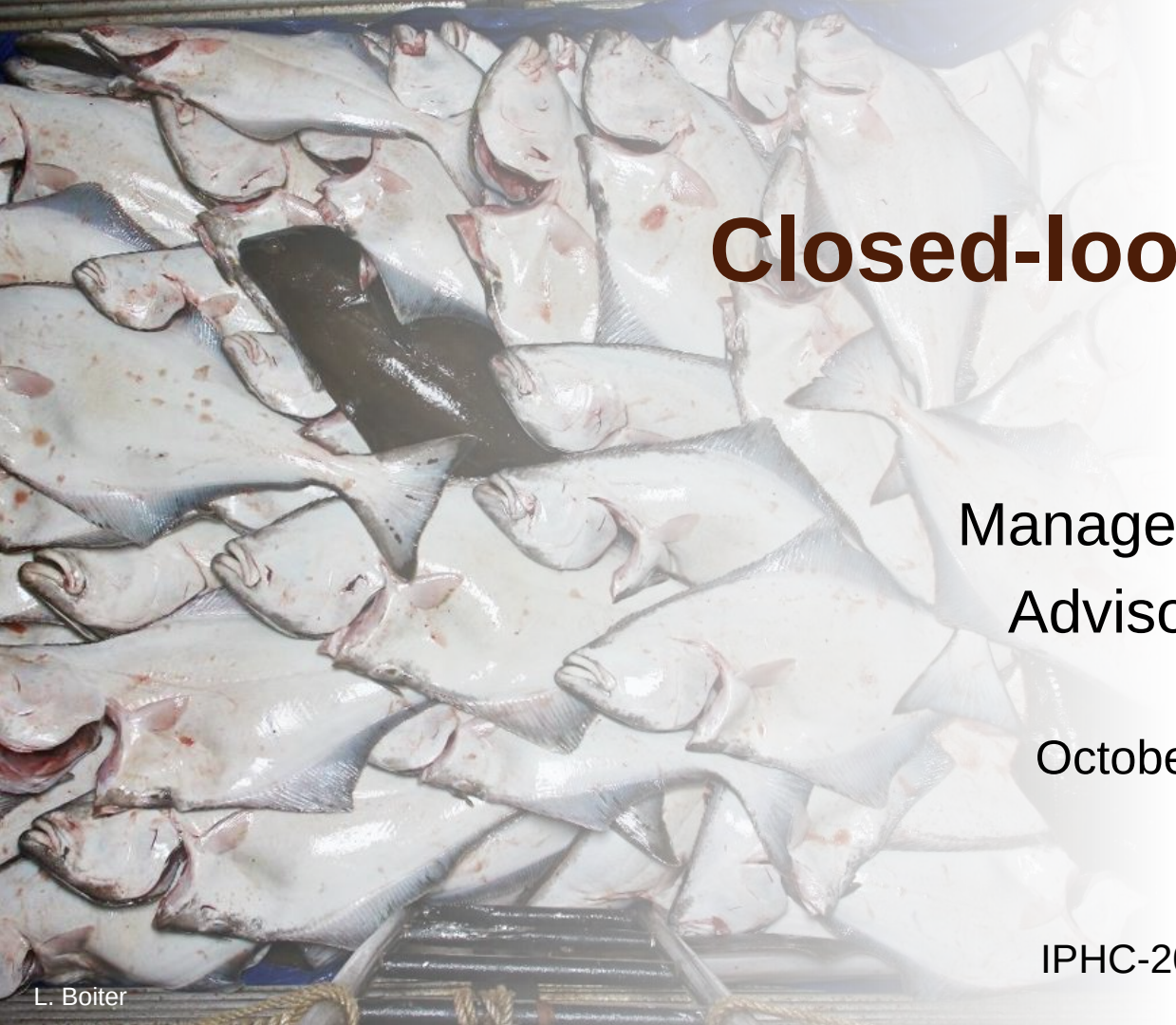


Closed-loop simulations

Management Strategy
Advisory Board 10

October 23-26, 2017

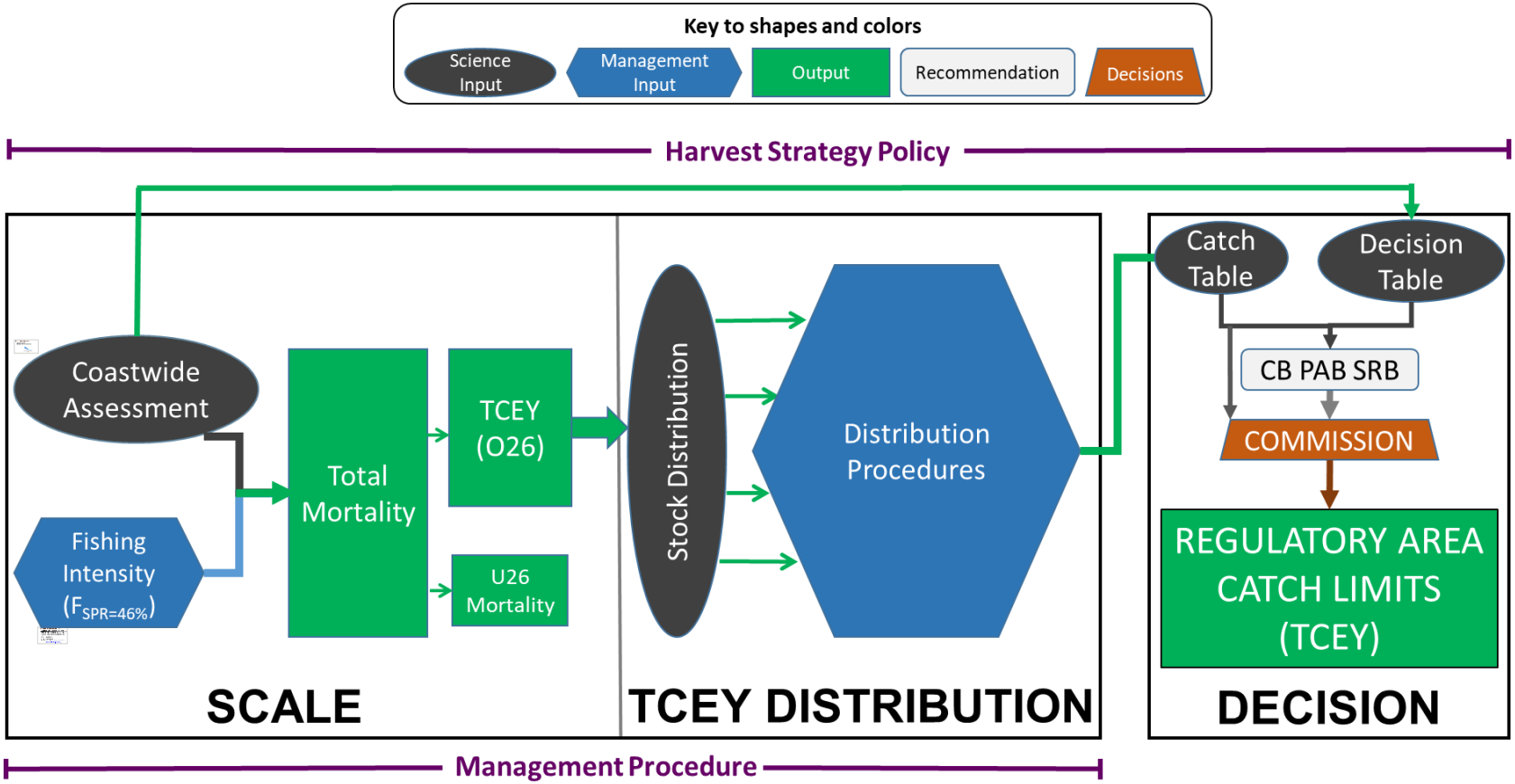
IPHC-2017-MSAB10-09

L. Boiter

Outline

- Recap of the harvest strategy policy and simulation framework
- Uncertainty
  - Total mortality to sectors
  - Weight-at-age
  - Environmental regimes
- Operating Model
- Simulation Results

Harvest Strategy Policy



IPHC stock assessment

- Coastwide assessment
- Ensemble of four assessment models
  - Robust method with an appropriate estimate of uncertainty

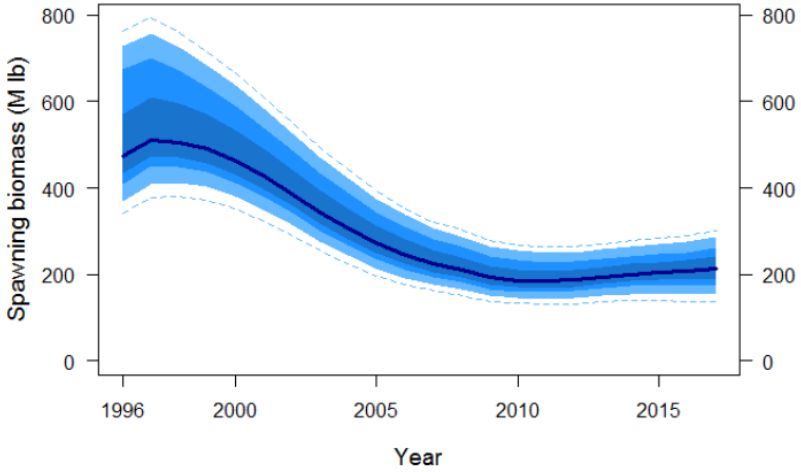


Figure 4. Estimated spawning biomass for the 2016 stock assessment ensemble.

Spawning Potential Ratio (SPR)

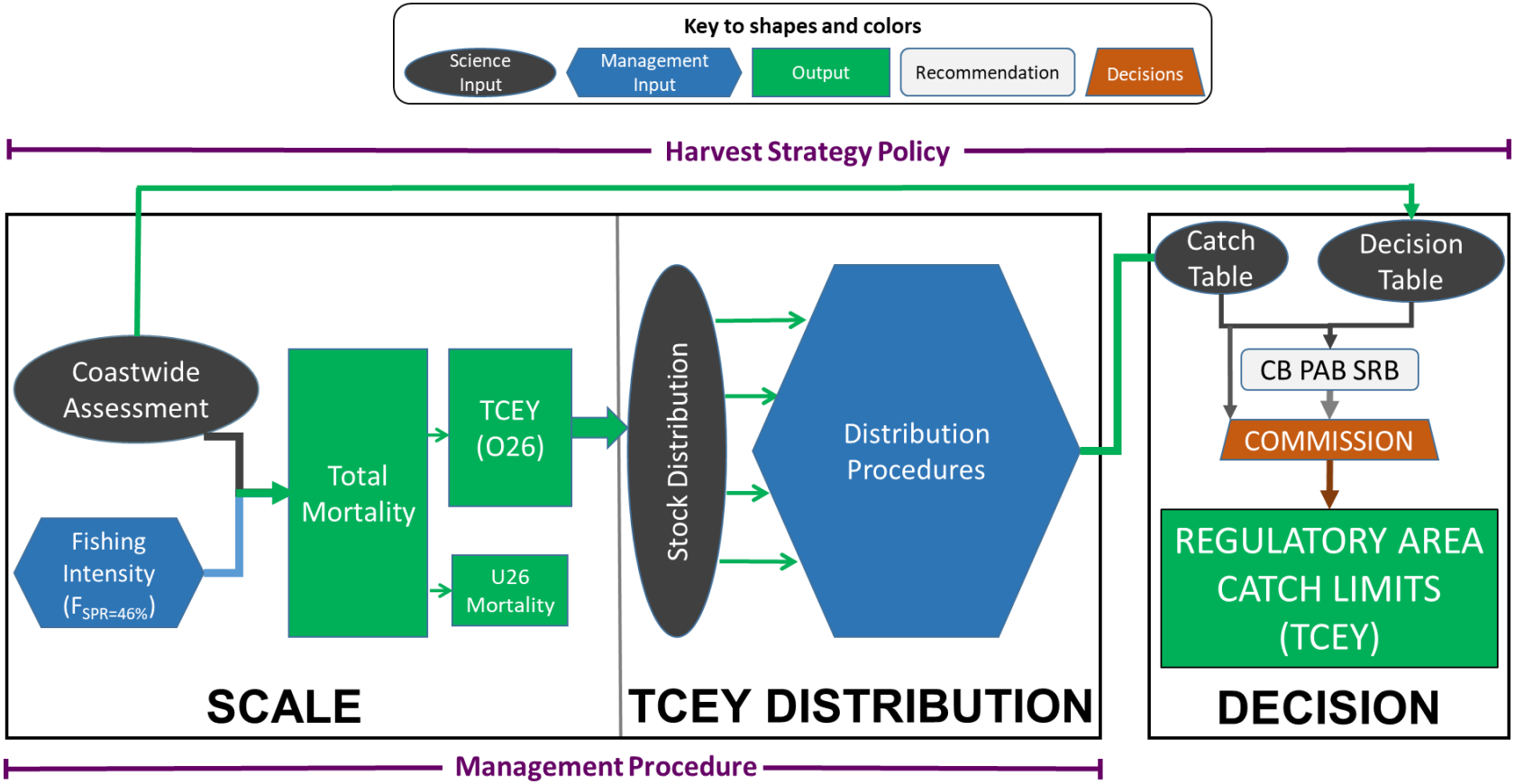
$$\frac{\text{Spawning Output Per Recruit with fishing}}{\text{Spawning Output Per Recruit with no fishing}}$$

divided by

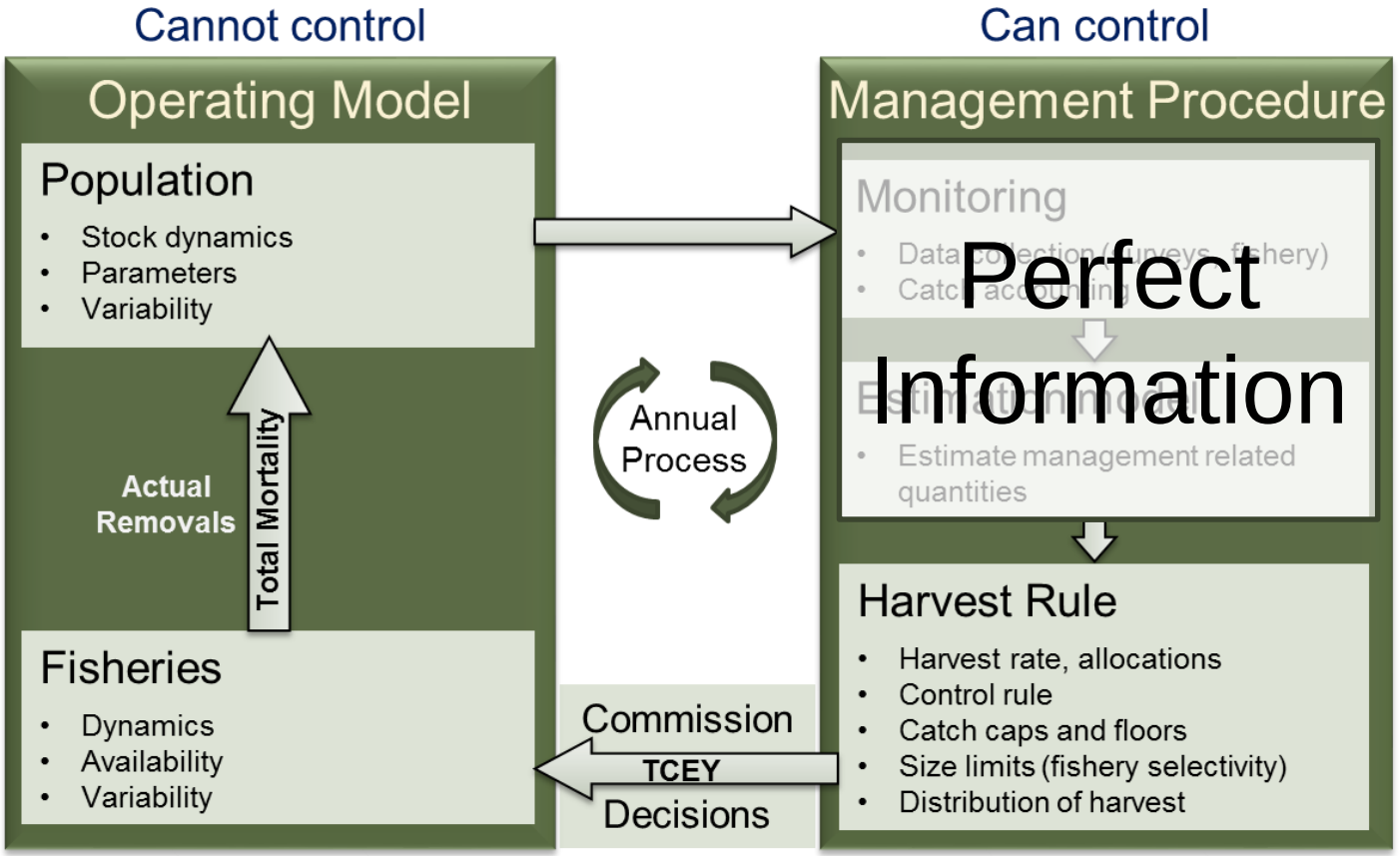
- A measure of the reduction in spawning potential due to fishing at a constant rate (F_{SPR})
- A long-term, average concept
- SPR=100% means no fishing
- SPR=40% means a 60% reduction in spawning potential

Coastwide Fishing Intensity

Harvest Strategy Policy



Simulation Framework



Perfect Information

- Data generation and Estimation Model were not simulated
  - Ran out of time to do properly
  - We are not evaluating specific procedures related to these
- Perfect Info simulations provide a best case evaluation, and can be used to
  - Determine what procedures are reasonable
  - Narrow down the set to simulate/evaluate

Summary

- Operating Model
  - Stock synthesis, based on coastwide assessment models (short and long)
  - Five fleets, as in assessment
    - commercial, discard mortality, bycatch, recreational, subsistence.

Fishery Fleets

- **Commercial**: directed commercial fishery, no discards
- **Discard Mortality (DM)**: mortality in the commercial fishery that is not landed (formerly wastage)
- **Bycatch**: mortality from fisheries not targeting Pacific halibut
- **Recreational:** mortality from recreational/sport fisheries
- **Subsistence:** mortality for subsistence/personal use purposes

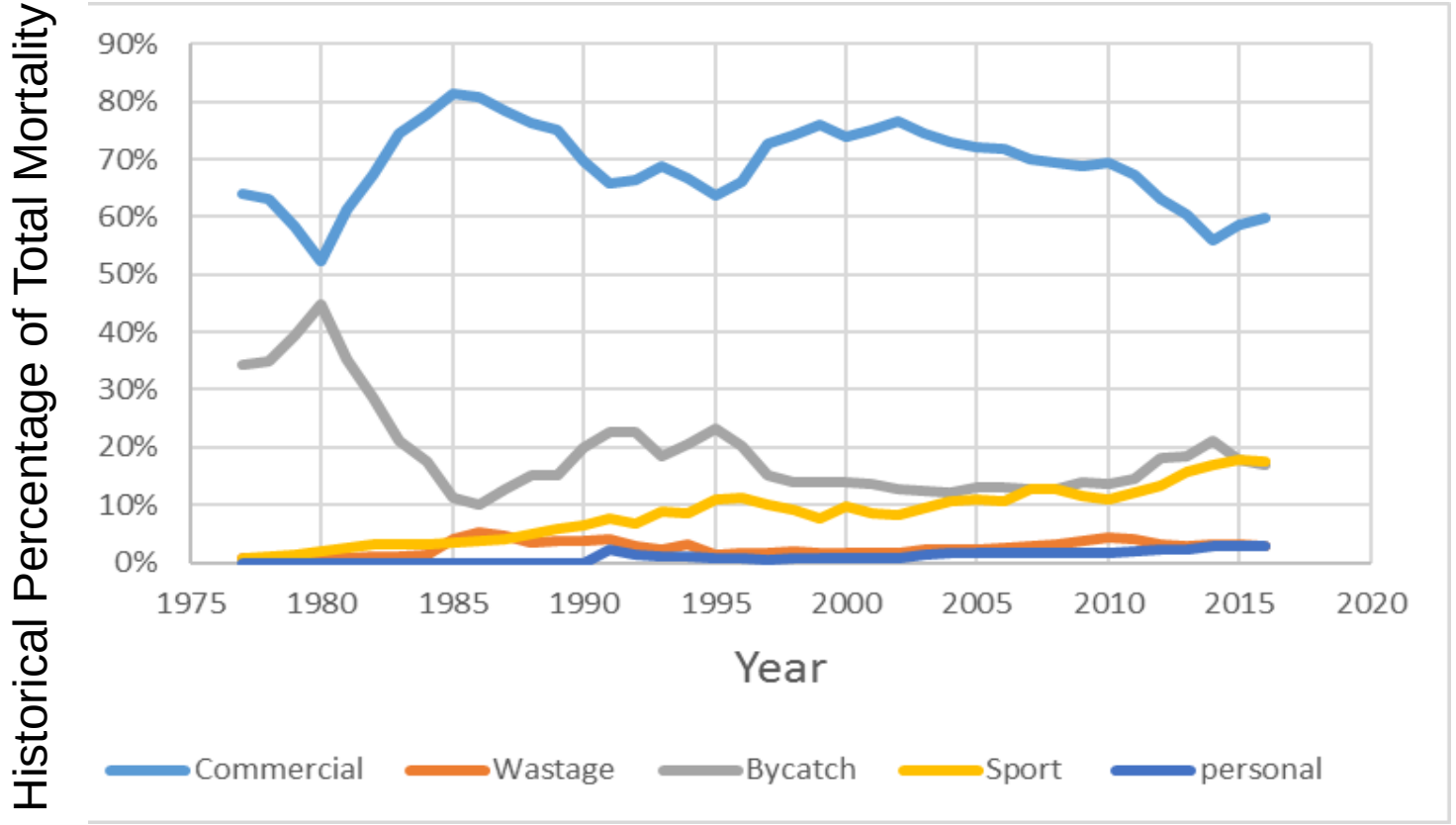
Summary

- Operating Model
  - Stock synthesis, based on coastwide assessment models (short and long)
  - Five fleets, as in assessment
    - commercial, discards, bycatch, recreational, subsistence.
  - Parameter uncertainty and model uncertainty.
- Estimation Models
  - Perfect Information (if we knew population values exactly)
- Management Procedure
  - Constant catch
  - A coastwide fishing intensity (F_{SPR})
  - A control rule
  - Catch assigned to sectors based on historical information (with variability)
- Data Generation
  - Not needed at this time.

Additional uncertainty (scenarios)

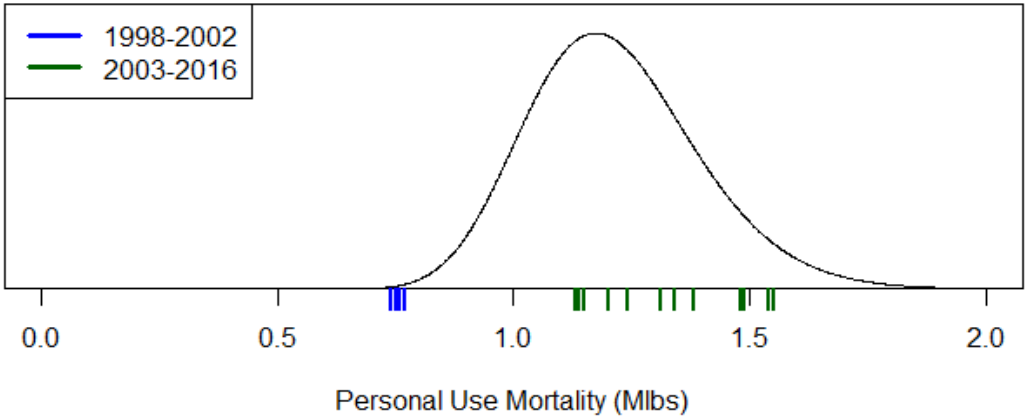
Process	Uncertainty
Natural Mortality (M)	Estimate appropriate uncertainty when conditioning OM
Recruitment	Random, lognormal deviations
Size-at-age	Annual and cohort deviations in size-at-age with bounds
Steepness	Estimate appropriate uncertainty when conditioning OM
Regime Shifts	Autocorrelated indicator based on properties of the PDO for regime shift
TM to sectors	See section on allocating TM to sectors
Proportion of TCEY	Sector specific. Sum of mortality across sectors may not equal coastwide TM

Allocating total mortality



Personal Use/Subsistence

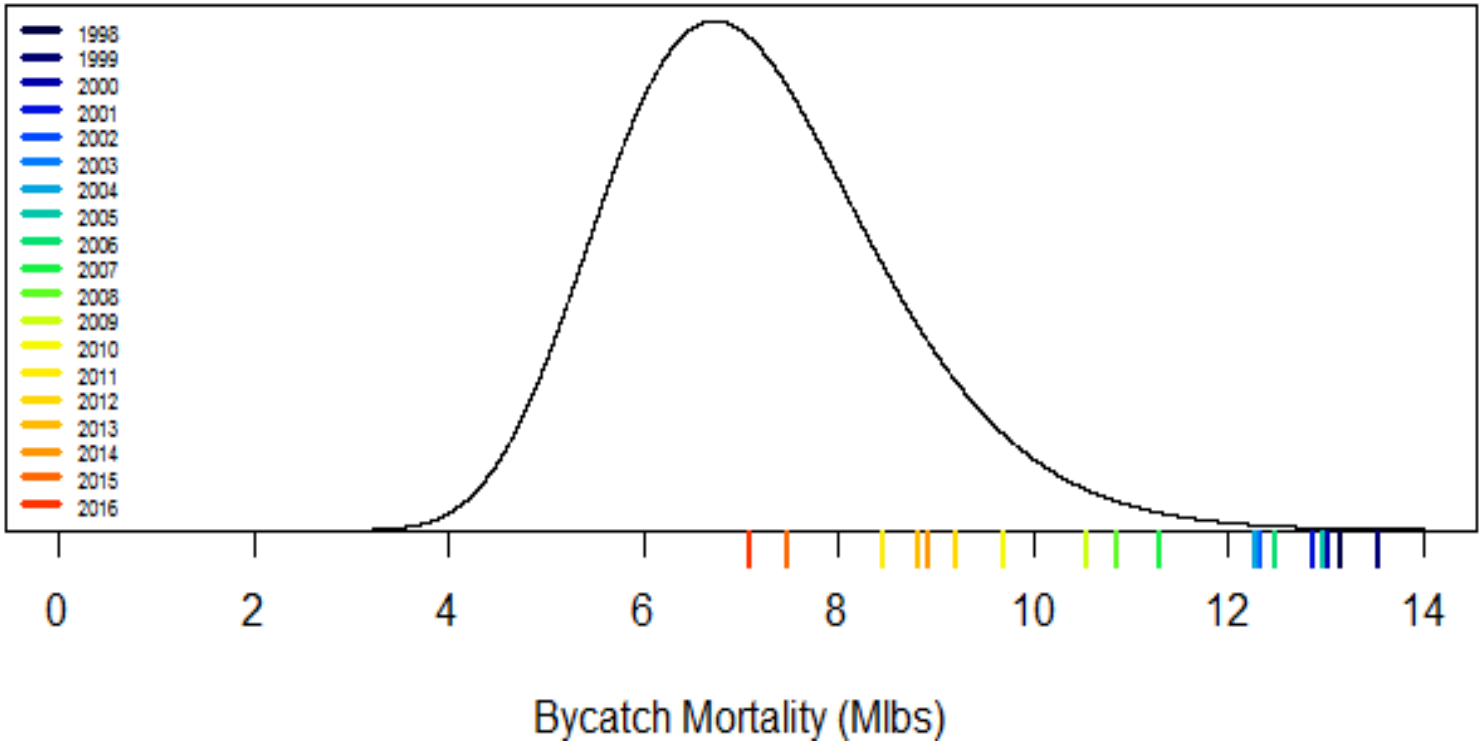
- Between 1.1 Mlbs and 1.5 Mlbs for the last ten years
- 1.20 Mlbs for the last three years
- Random draw from lognormal(median=1.2Mlbs,cv=15%)
  - 5^{th} & 95^{th} percentiles of 0.9 and 1.5 Mlbs
- Minimum of 0.5 Mlbs



Bycatch

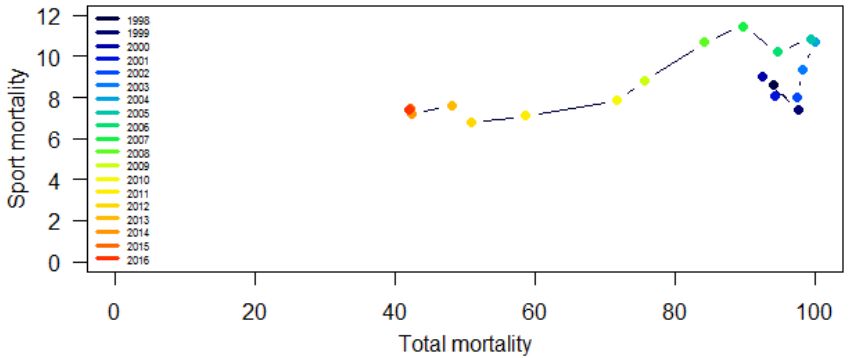
- Typically managed with limits, although these limits are not often reached
- Has been declining in recent years
- Not easily predicted
- Lognormal(median=7Mlbs, cv=20%)
  - 5^{th} & 95^{th} percentiles: 5 and 9.7 Mlbs

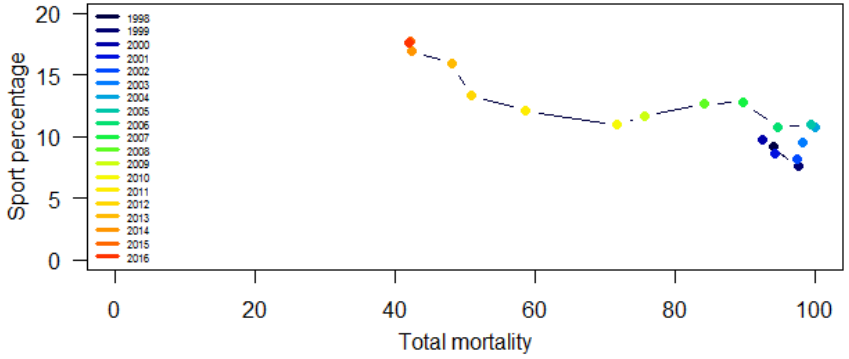
Bycatch


1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
0
2
4
6
8
10
12
14
Bycatch Mortality (Mlbs)

Recreational fishery

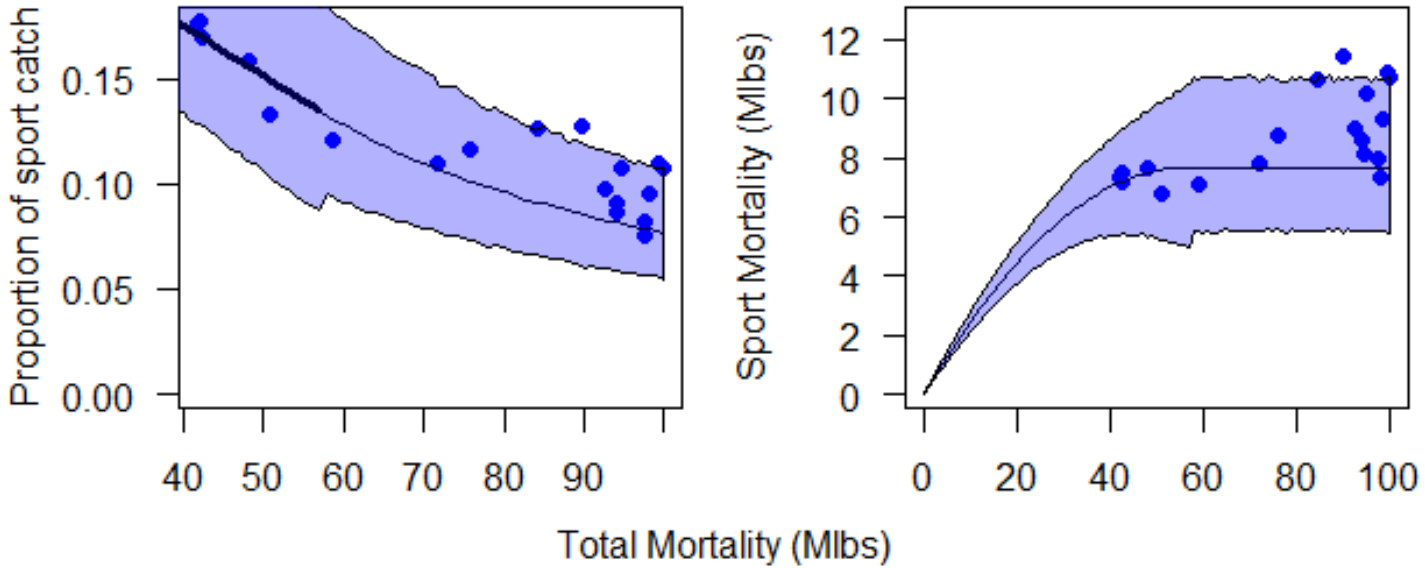
- Around 11% or 7.6 Mlbs in early 2000's when coastwide Total Mortality greater than 57Mlbs
- Since 2011, larger than 11%, but around 7 Mlbs when coastwide Total Mortality less than 57 Mlbs





Recreational fishery

- TM>57Mlbs: Lognormal(median=7,682 Mlbs, cv=20%)
- TM<57Mlbs: Proportion declining linear relationship w/ TM

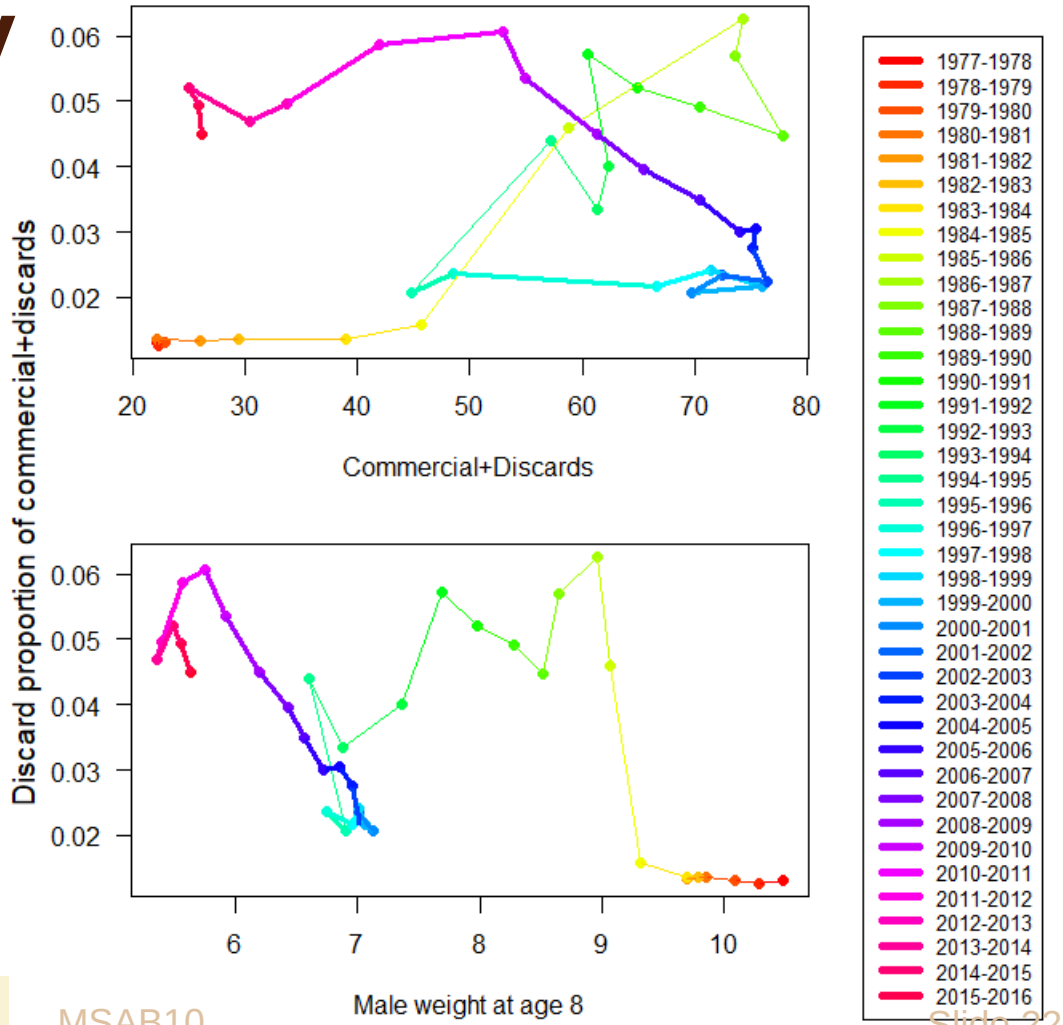


Discard mortality (DM)

- Commercial+DM
  - Remainder after personal, bycatch, sport removed
- Higher TM, more fishing
  - Thus discards should be higher
- DM related to size
  - When size is small, discards higher

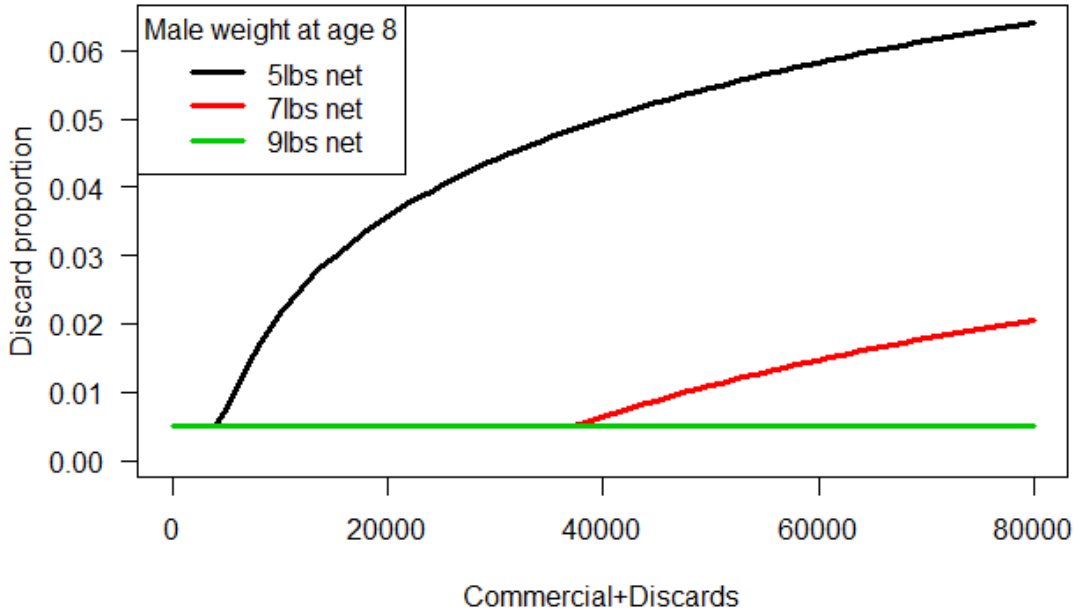
Discard mortality

- Derby ended in 1995
- Using data from 1996-2016
  - 4 models using commercial + discards and weight-at-age

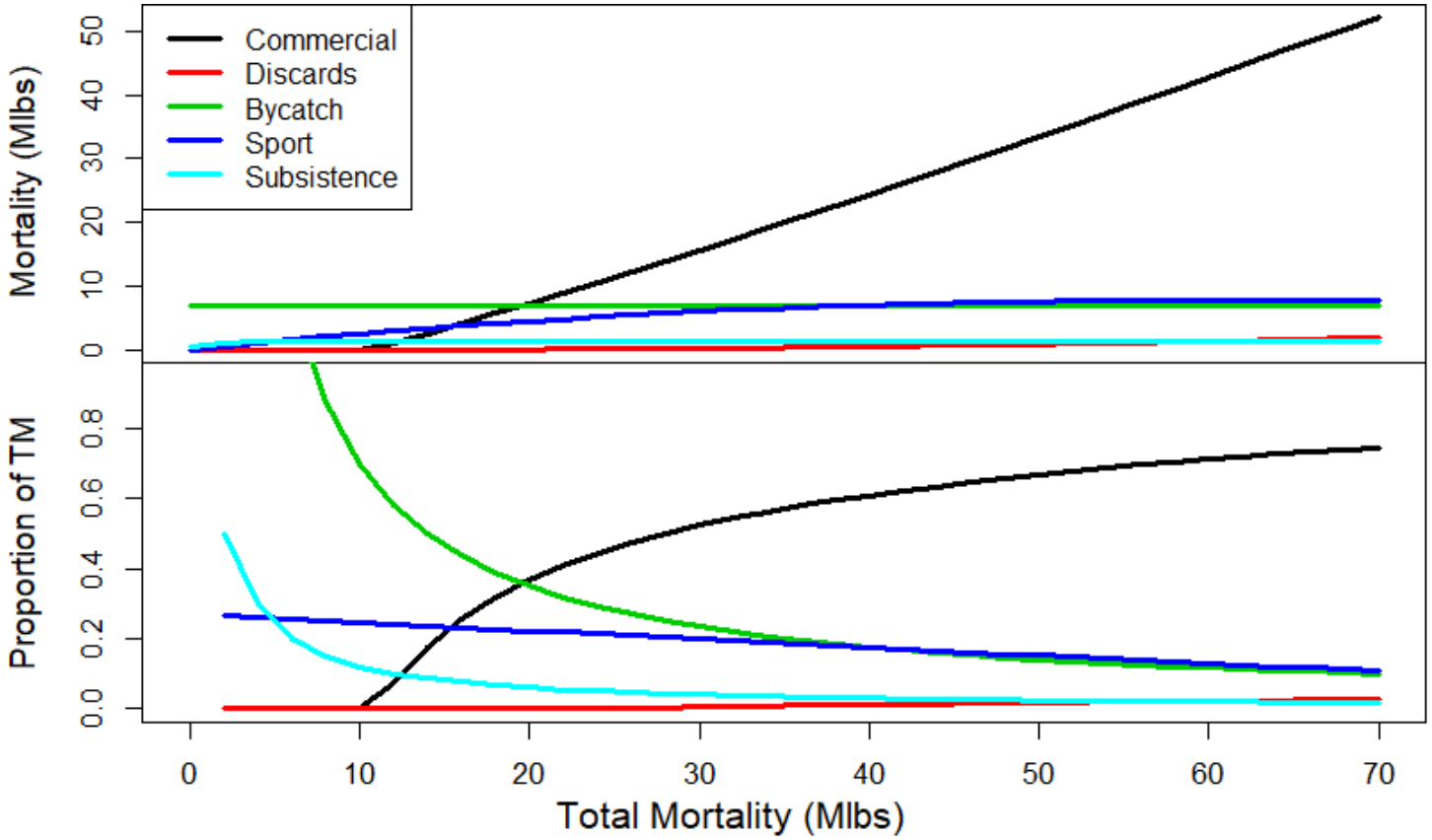


Predicting Discards

- A base level of discard mortality that changes with changes to weight-at-age
- A somewhat arbitrary level of uncertainty



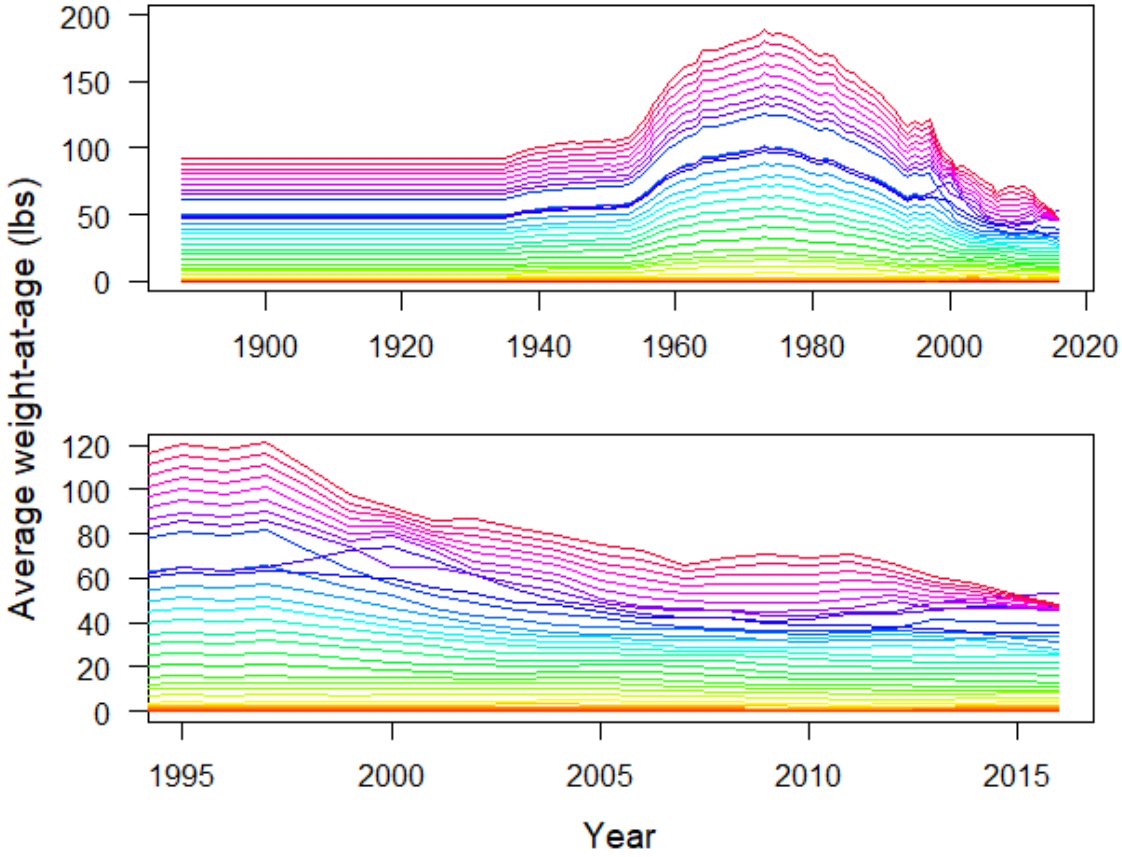
Expected allocated total mortality



Simulating weight-at-age

- Important behaviors of the historical time-series
  1. age-specific weights-at-ages tend to increase and decrease in the same year
     - little evidence of lags for a cohort
  2. time-series appears to be similar to a random walk with smooth trends and few large jumps in observations
     - partly due to the smoothing that was done
  3. there appears to be some ages that do not follow the general trend
     - evident at the end of the time series where the sampling was likely greater

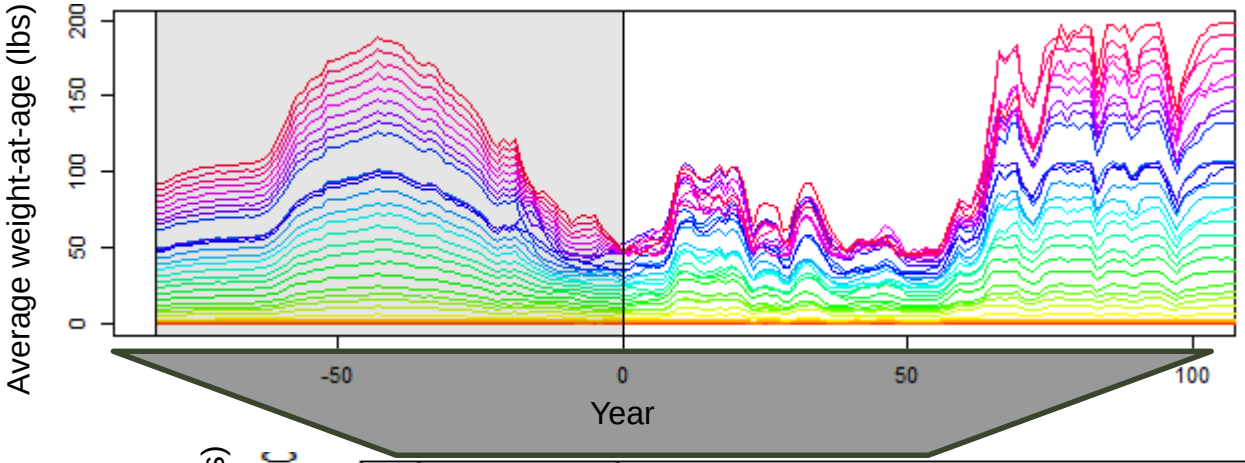
Historical Weight-at-age

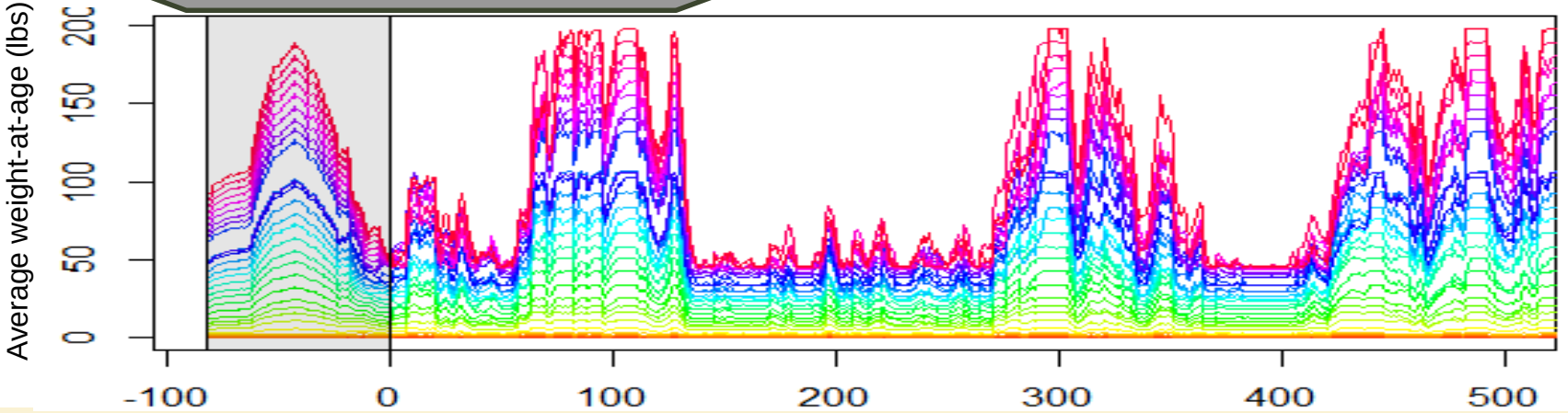


Method to simulate weight-at-age

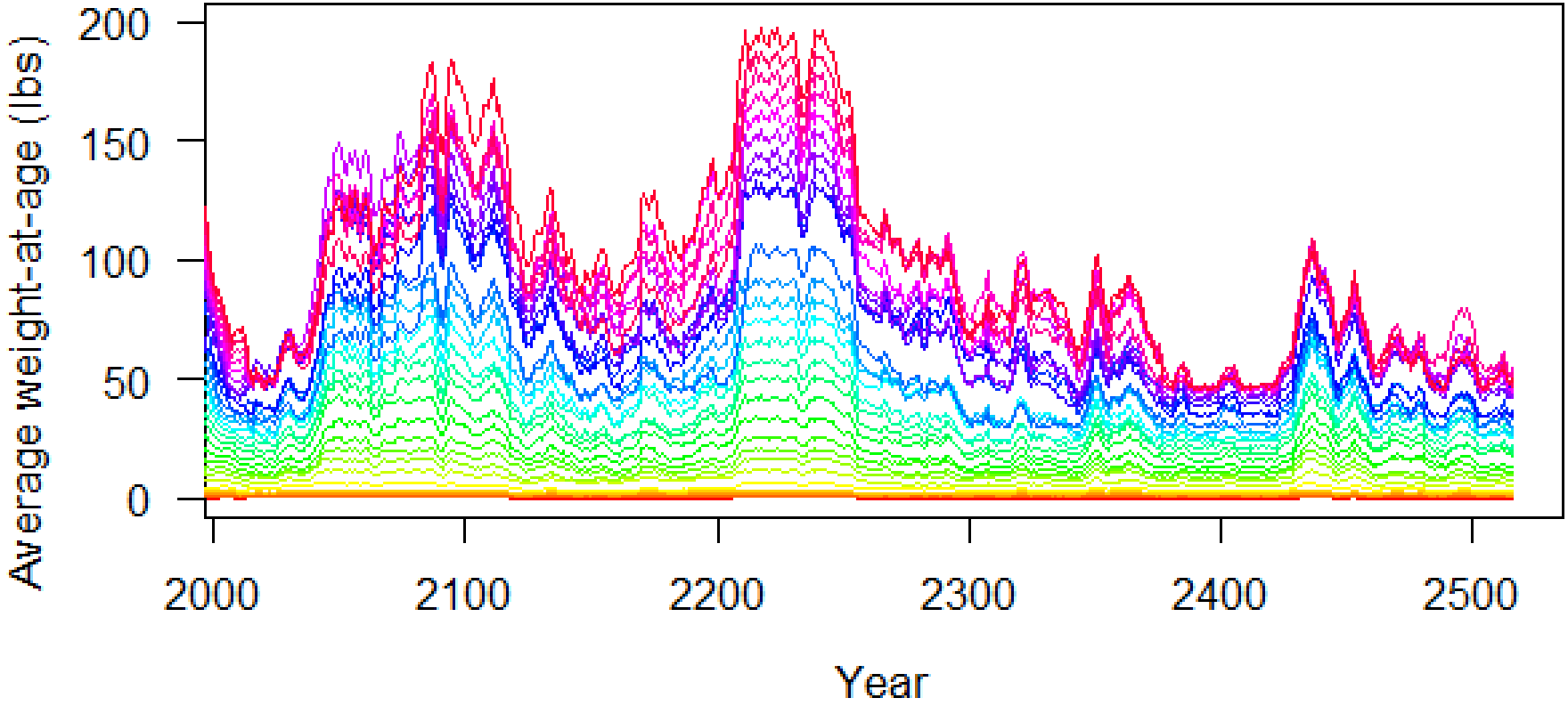
- Random walk with two deviations
  1. Autocorrelated multiplier on current years weight-at-age to determine the weight-at-age in the next year
     - All weights for each age increase or decrease similarly.
  2. Deviations for each age 6 and greater
     - Mechanism for the mean weight of a specific age to depart from the overall trend (simulated in step 1)
     - Larger deviations for older (larger) fish
- Boundary limits expanded 5% beyond the minimum and maximum observed weight at each age

Simulated Weight-at-age



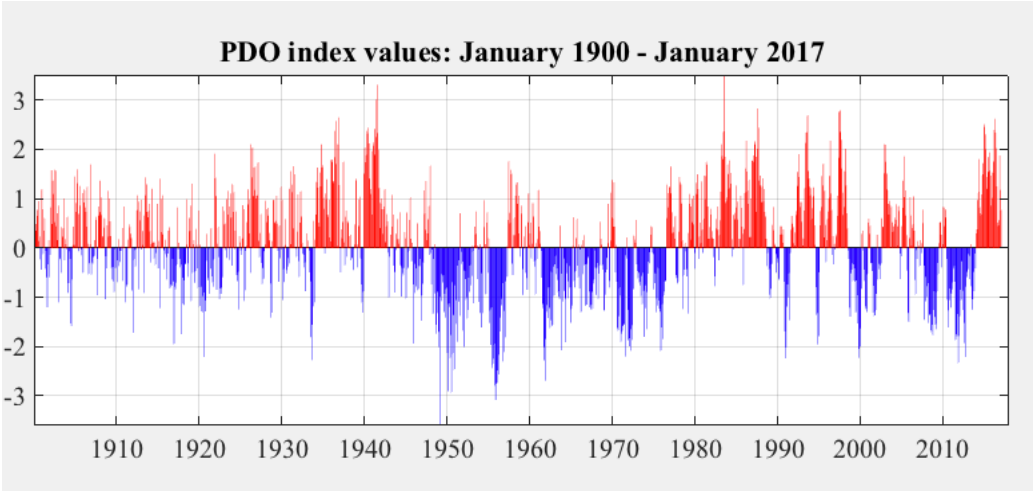


Simulated weight-at-age (2)

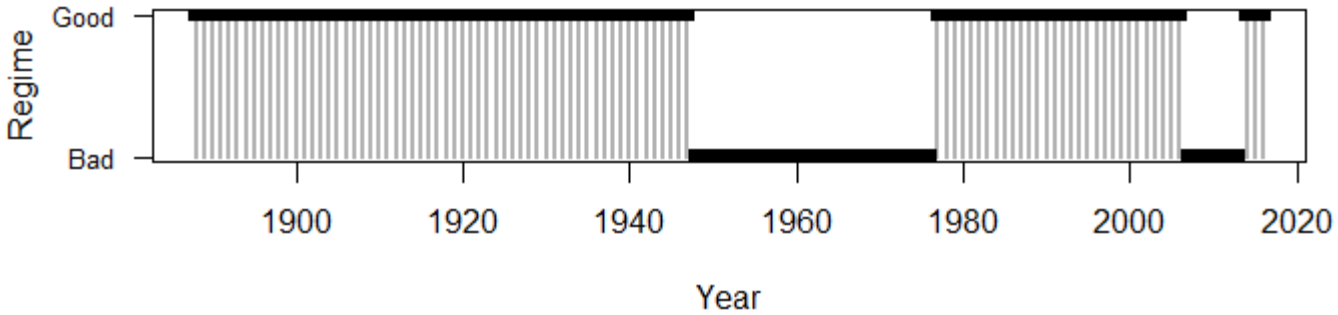


Regime shifts

- Good/Bad recruitment regime linked to PDO



From Assessment

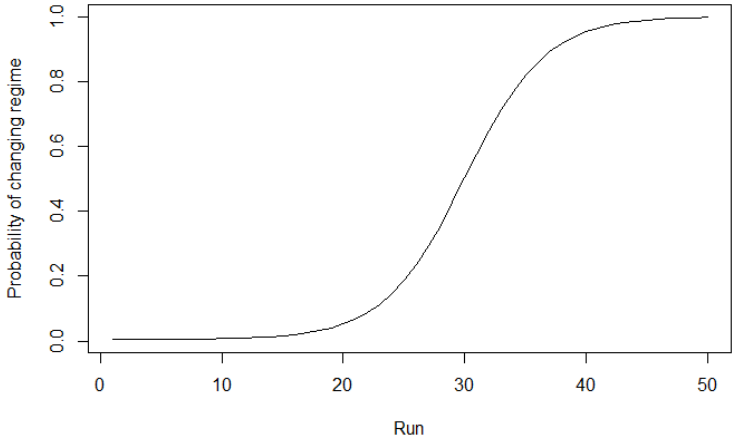


Recruitment regimes

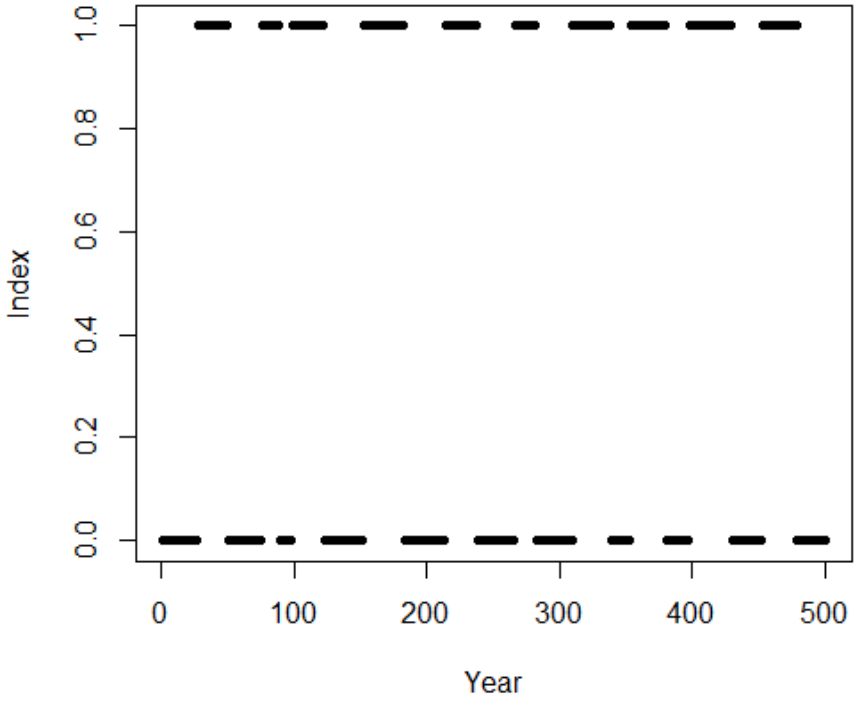
- The regime affects average recruitment
  - Long model
    - Ratio good:bad = 1.38 (0.99 – 1.93)
  - Short model
    - Ratio good:bad = 3.15 (fixed from historical research)

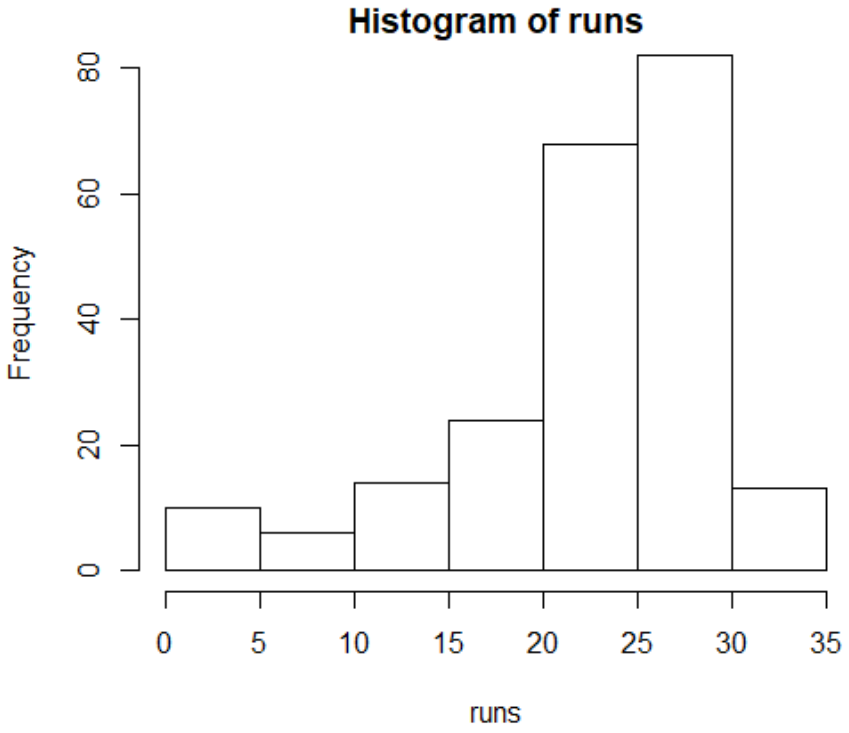
Environmental regime

- Semi-Markov process
  - Next year depends on this year's value and probability of change
  - Probability of change depends on how long since it changed (Run)



Simulated Environmental Regime





Recap of scenarios

Process	Uncertainty
Natural Mortality (M)	Estimate appropriate uncertainty when conditioning OM
Recruitment	Random, lognormal deviations
Size-at-age	Annual and cohort deviations in size-at-age with bounds
Steepness	Estimate appropriate uncertainty when conditioning OM
Regime Shifts	Autocorrelated indicator based on properties of the PDO for regime shift
TM to sectors	See section on allocating TM to sectors
Proportion of TCEY	Sector specific. Sum of mortality across sectors may not equal coastwide TM

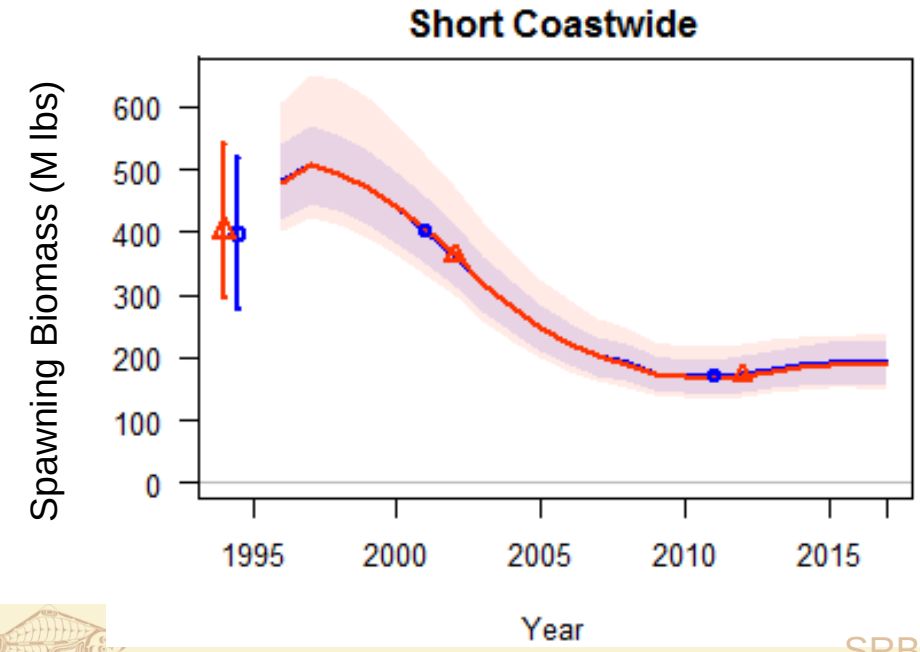
The operating model

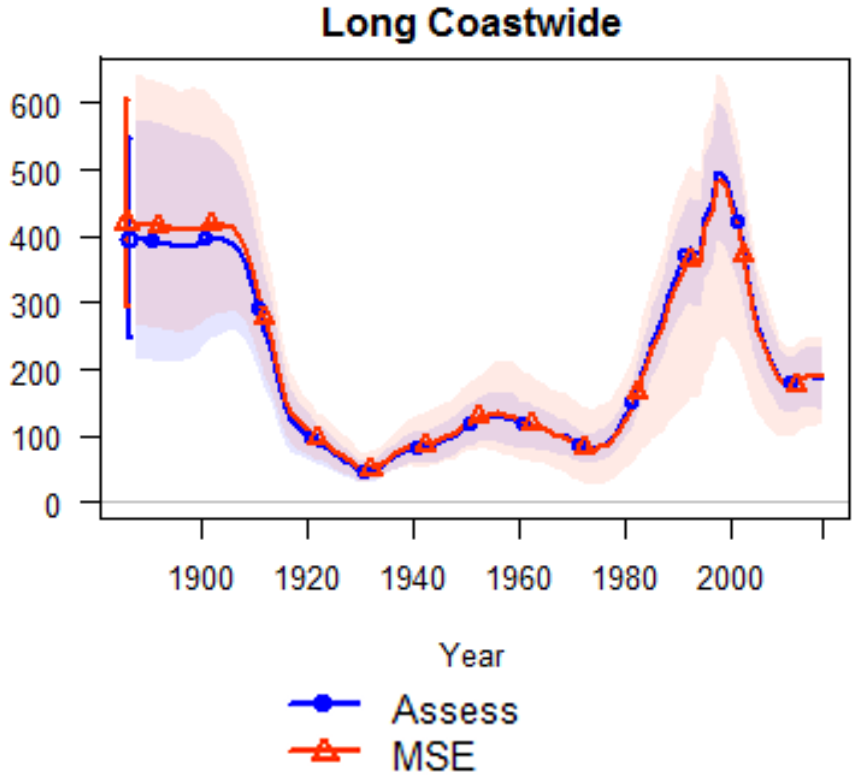
- Operating Model
  - Stock synthesis, based on coastwide assessment models
    - short and long models
  - Parameter uncertainty and model uncertainty

Conditioning OM

1. Match the stock assessment
   - Best available information
   - Use parameters estimated in assessment
   - Generate realizations from a truncated multivariate normal using the estimated Hessian
   - Run the ADMB model using each realization without estimation
   - Omit models that are outside “comfort level”
     - Minimum SB, maximum F
- Do this for all models

Matching the assessment



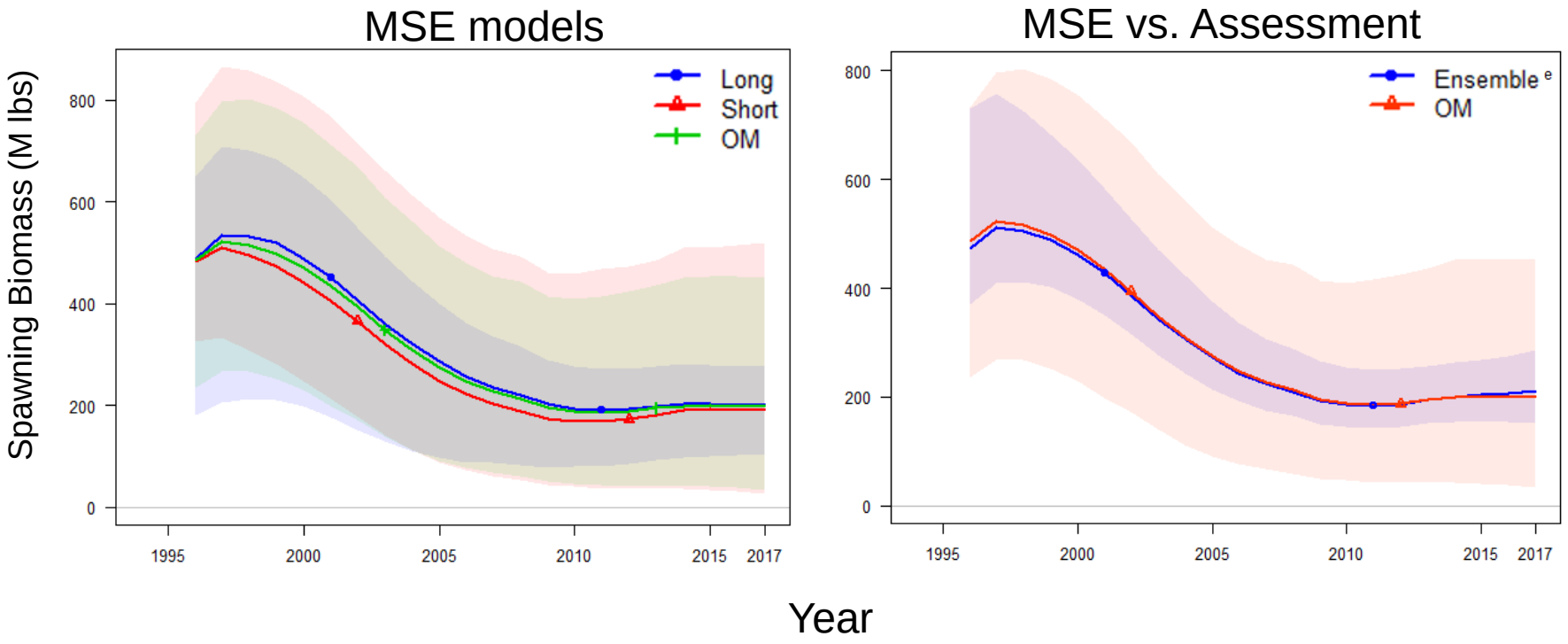


Conditioning OM (2)

2. Estimate Hessian with additional parameters estimated
3. Generate realizations from truncated MVN
   - Use assessment SDs (step 1)
   - Use additional parameter SDs (step 2)
   - Use correlations from (step 2)

- Do this for all models

Additional error in OM



Additions in future iterations

- Variable selectivity in the projections
- Covariates on weight-at-age
  - (e.g., density-dependence)
- Time-varying maturity-at-age
- An estimation model

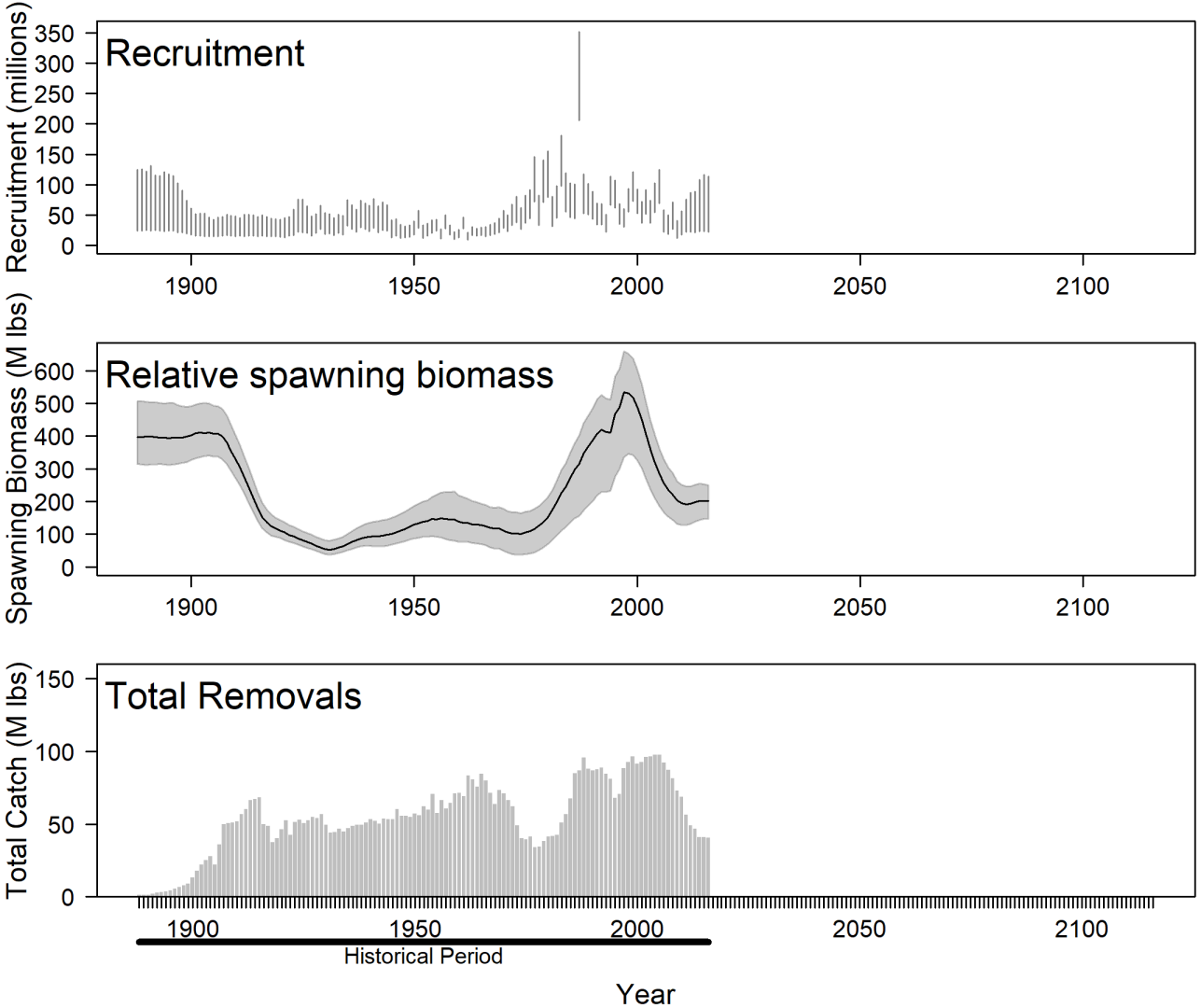
RESULTS

MSAB09 recommendations

Management Procedure	Values
SPR	0.25 – 0.60, higher density near 46%
Control Rule	30:20, 40:20 threshold and limit
Ceiling on Total Mortality	85 Mlbs
Floor on Total Mortality	30 Mlbs
Sensitivity	**Values**
Size-at-age	High and low states
Recruitment	High and low states
Maximum bycatch	At per-area maximum regulatory bycatch
Bycatch selectivity	Shifted to a greater proportion of U26 fish
Uncertainty in total mortality	Unknown

Example

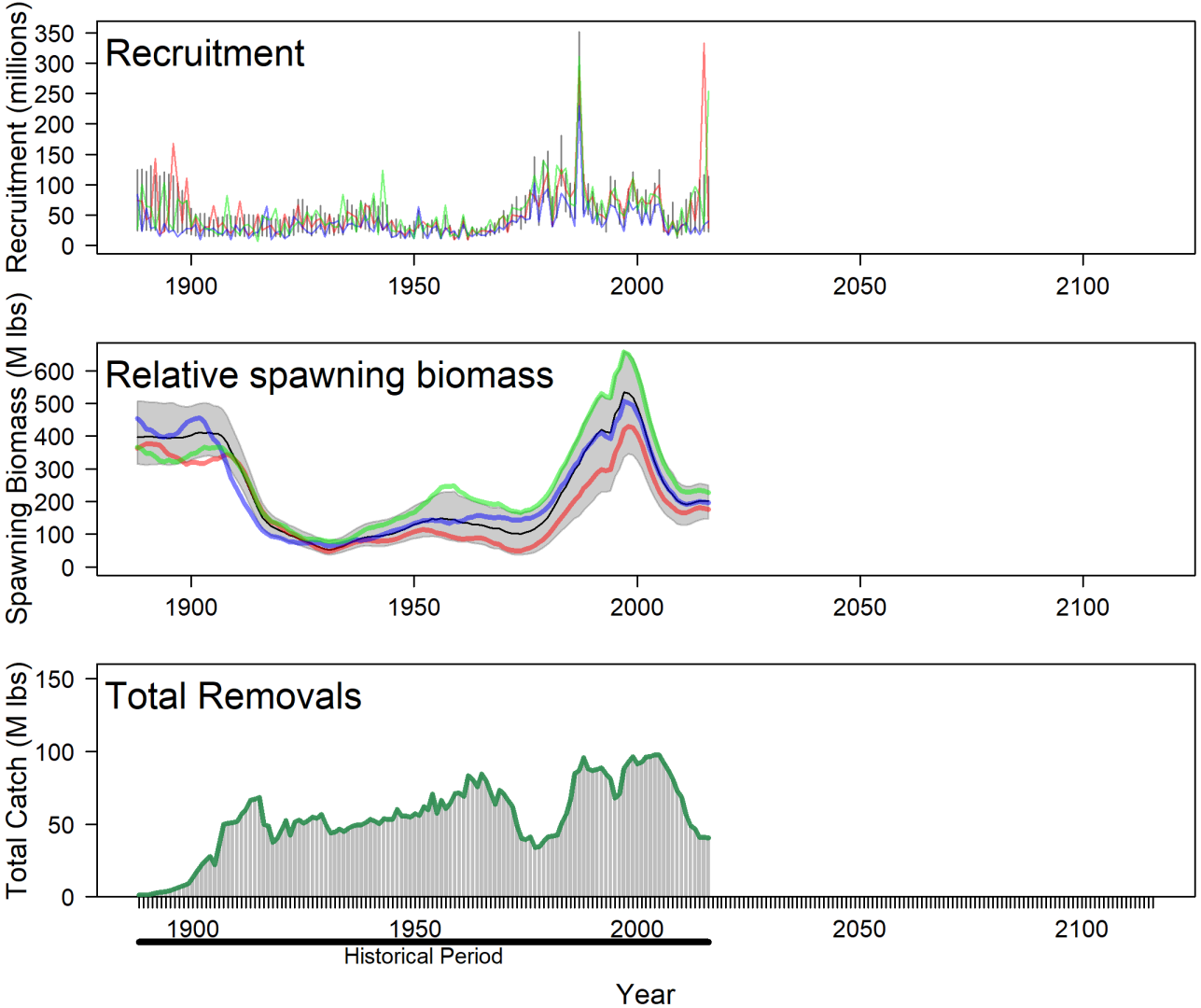
Operating Model



Inspired by Ian Taylor

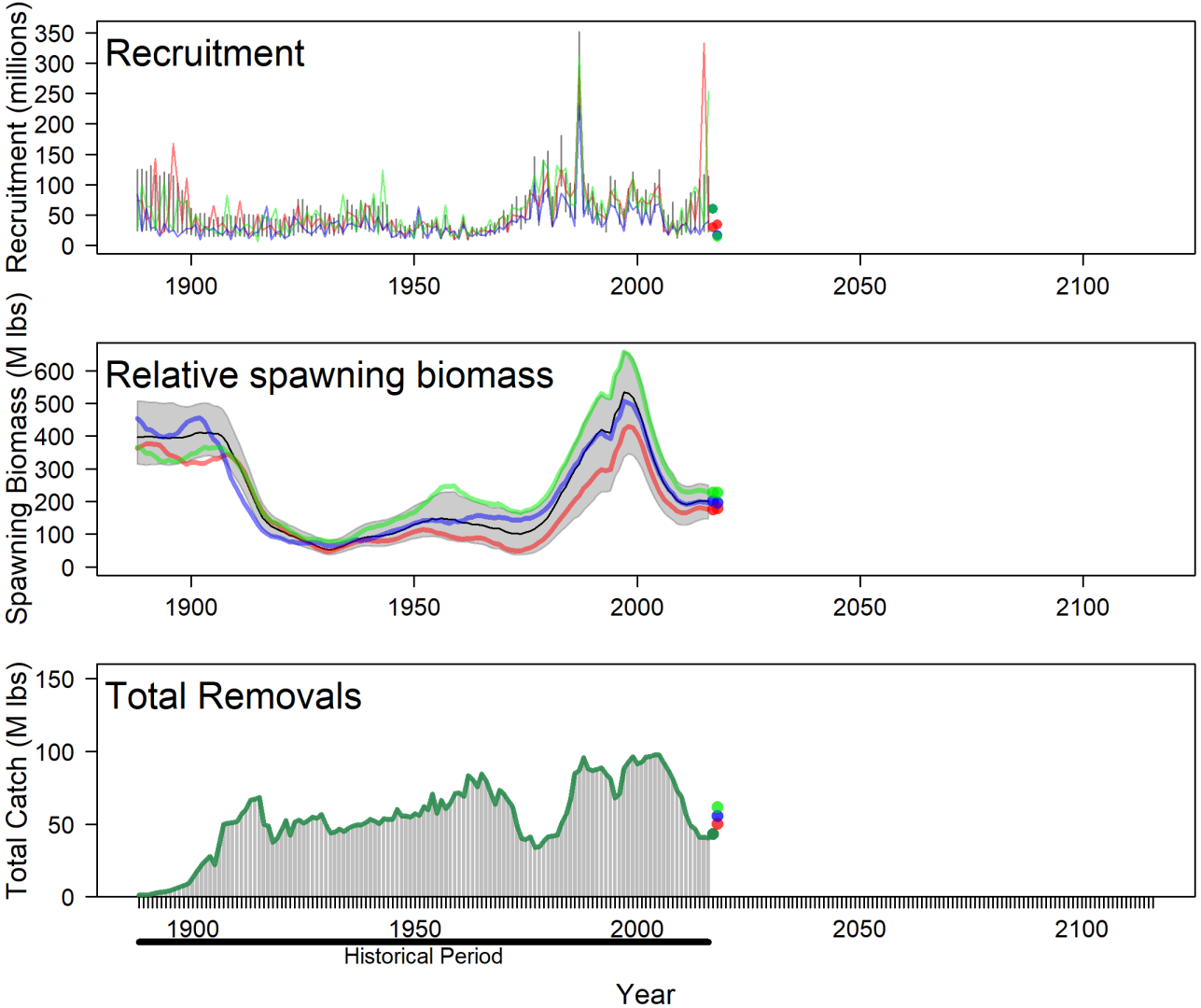
Example

Individual trajectories in the Operating Model



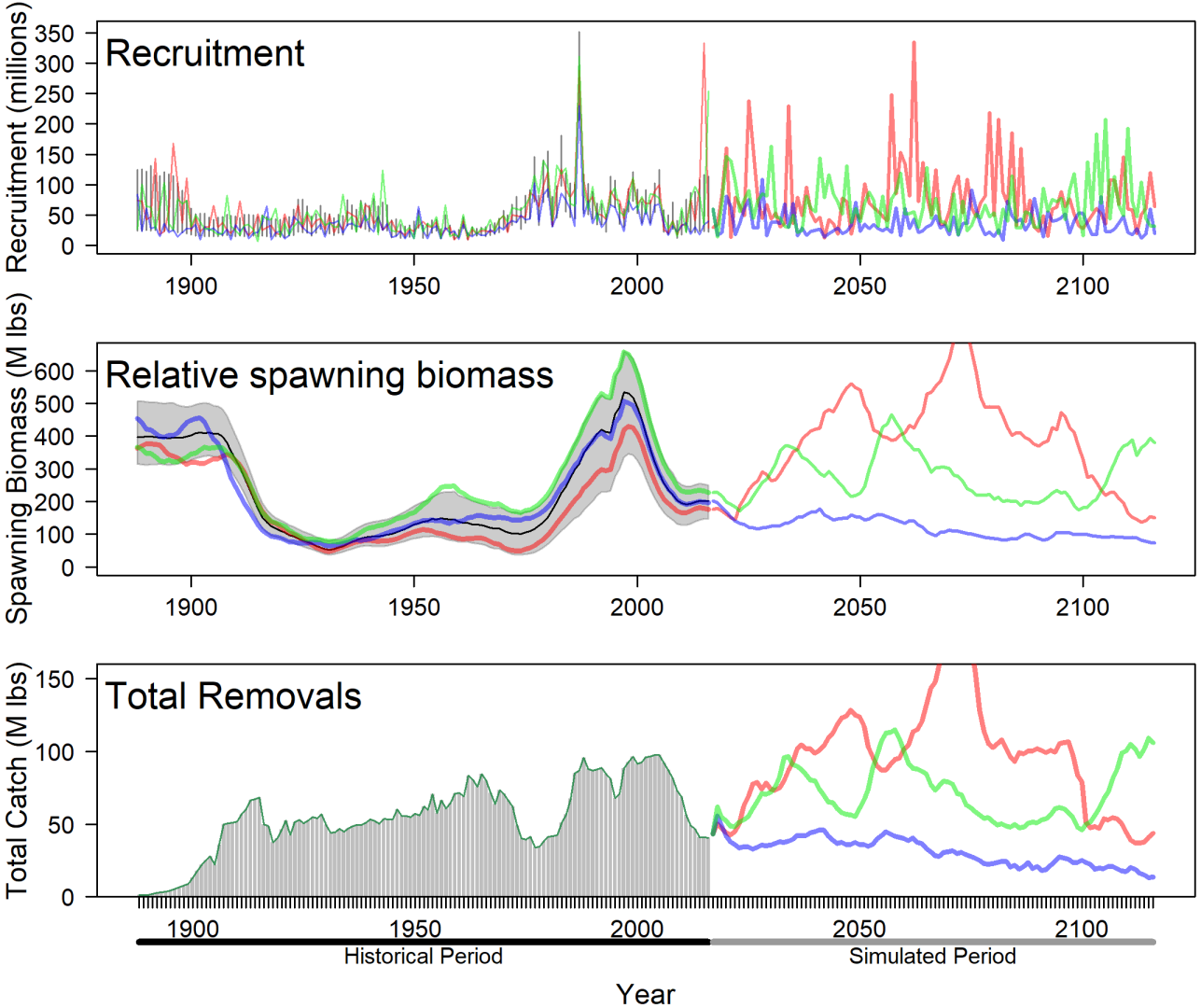
Example

Two years simulated forward



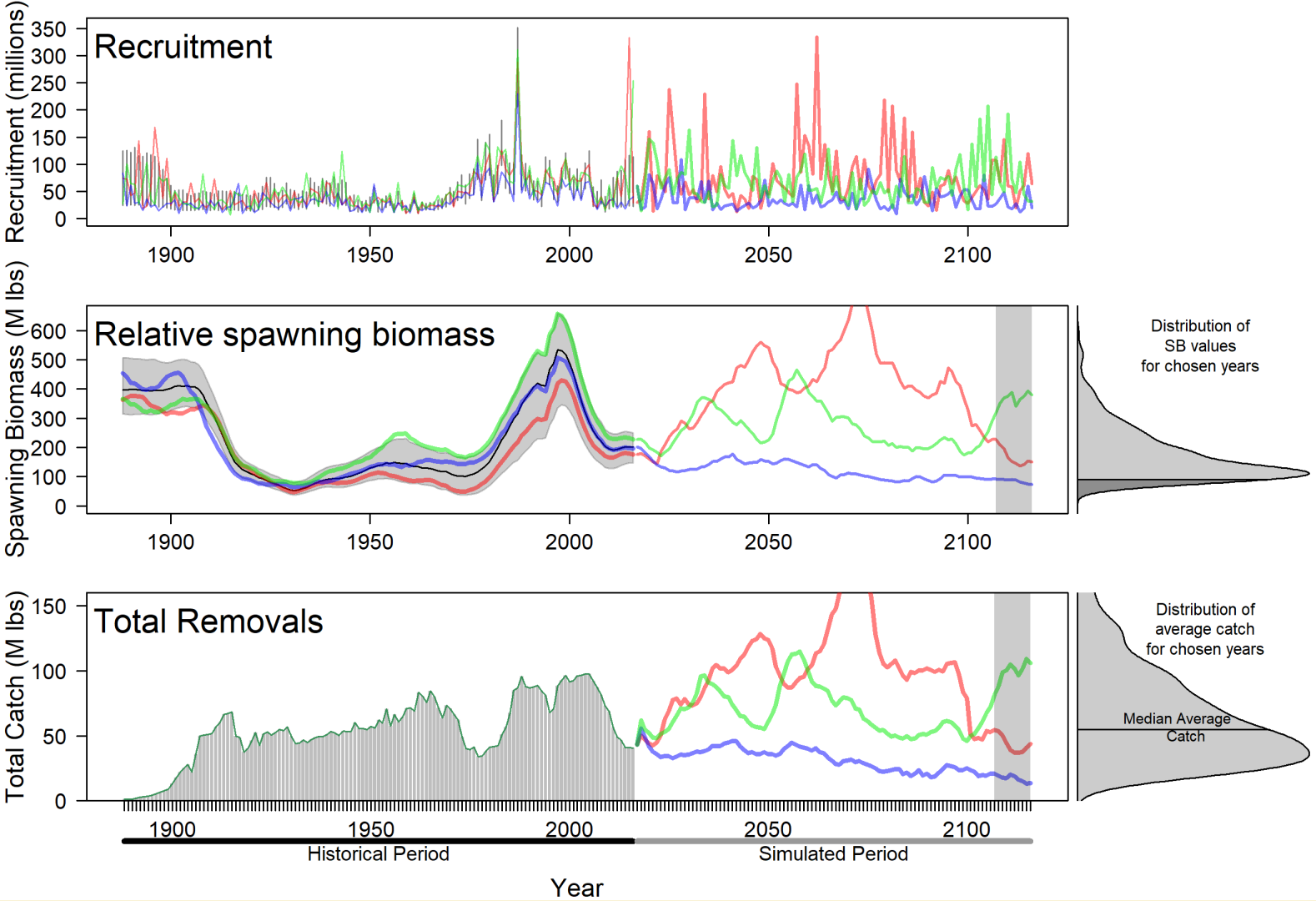
Example

100-year simulations



Example

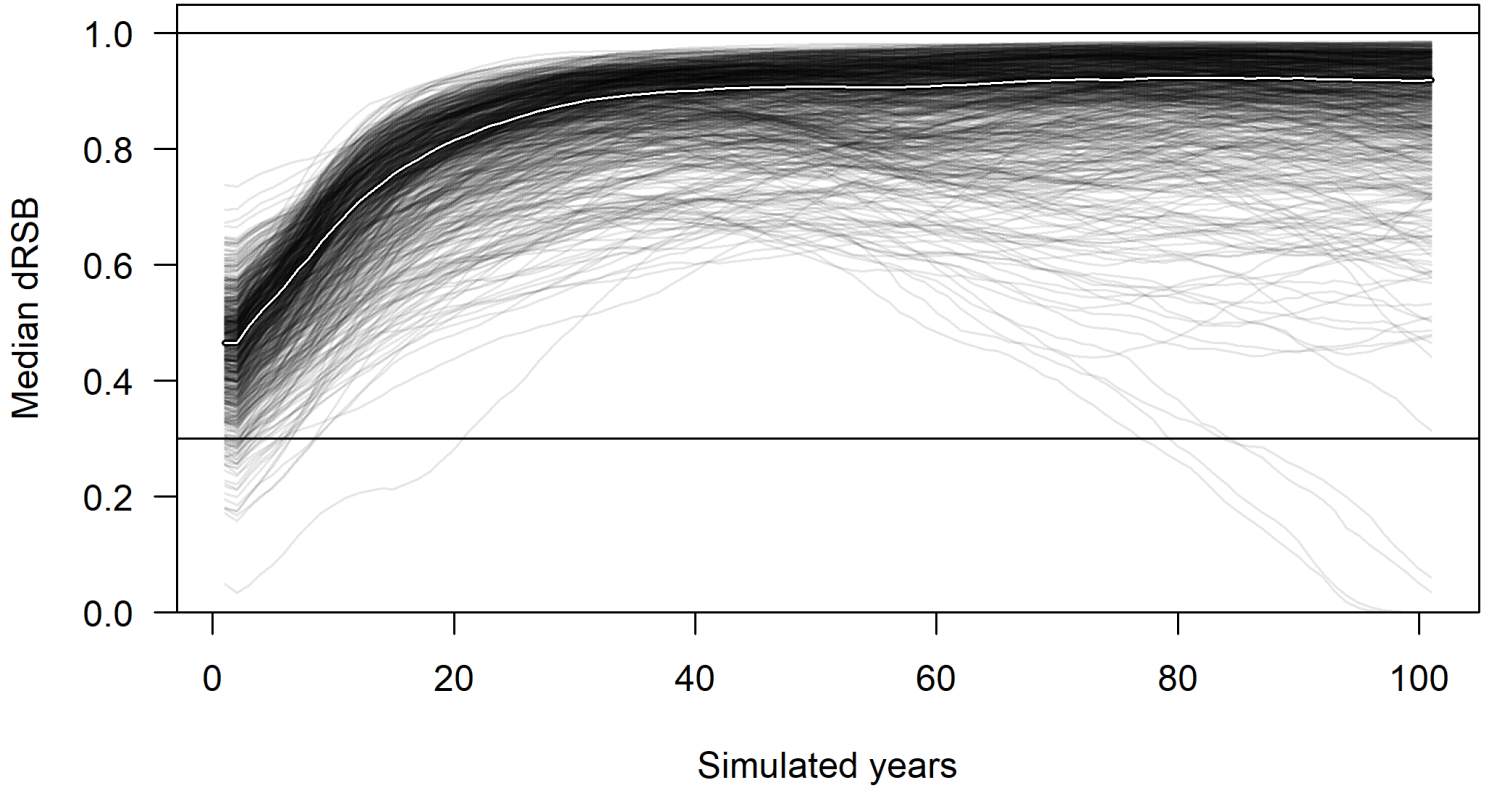
Summary statistics



Performance Metrics

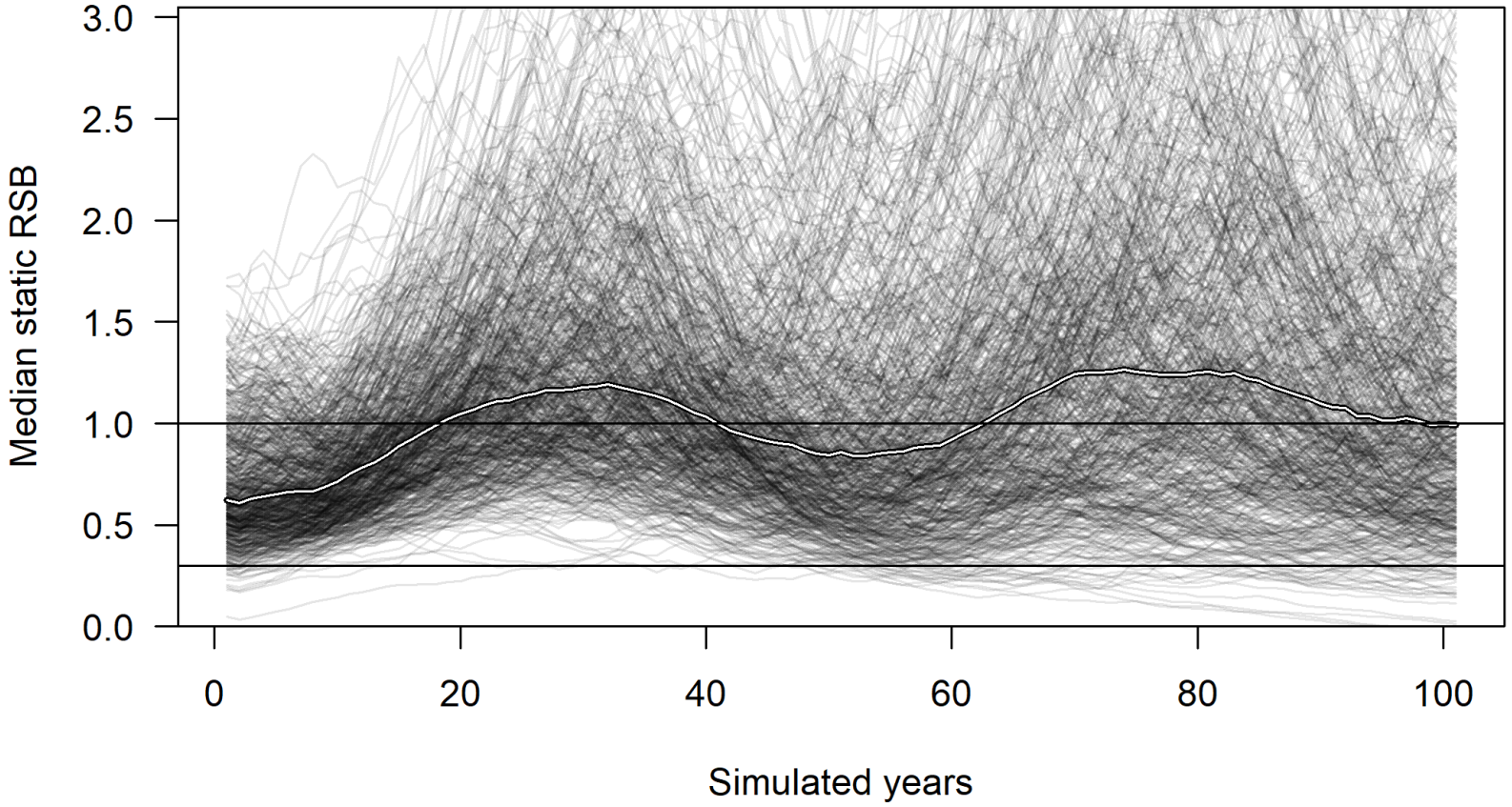
- Median average
  - 10-year average
  - Median of that average over simulations
- Probabilities
  - An event occurs in the final 10-year block and over simulations
    - (X out of 10,000)
  - An event occurs at least once within a 10-year block
    - Probability over simulations that this occurred
    - ($\tilde{X}$ out of 1000)

No directed fishing



Bycatch and (subsistence) mortality always present

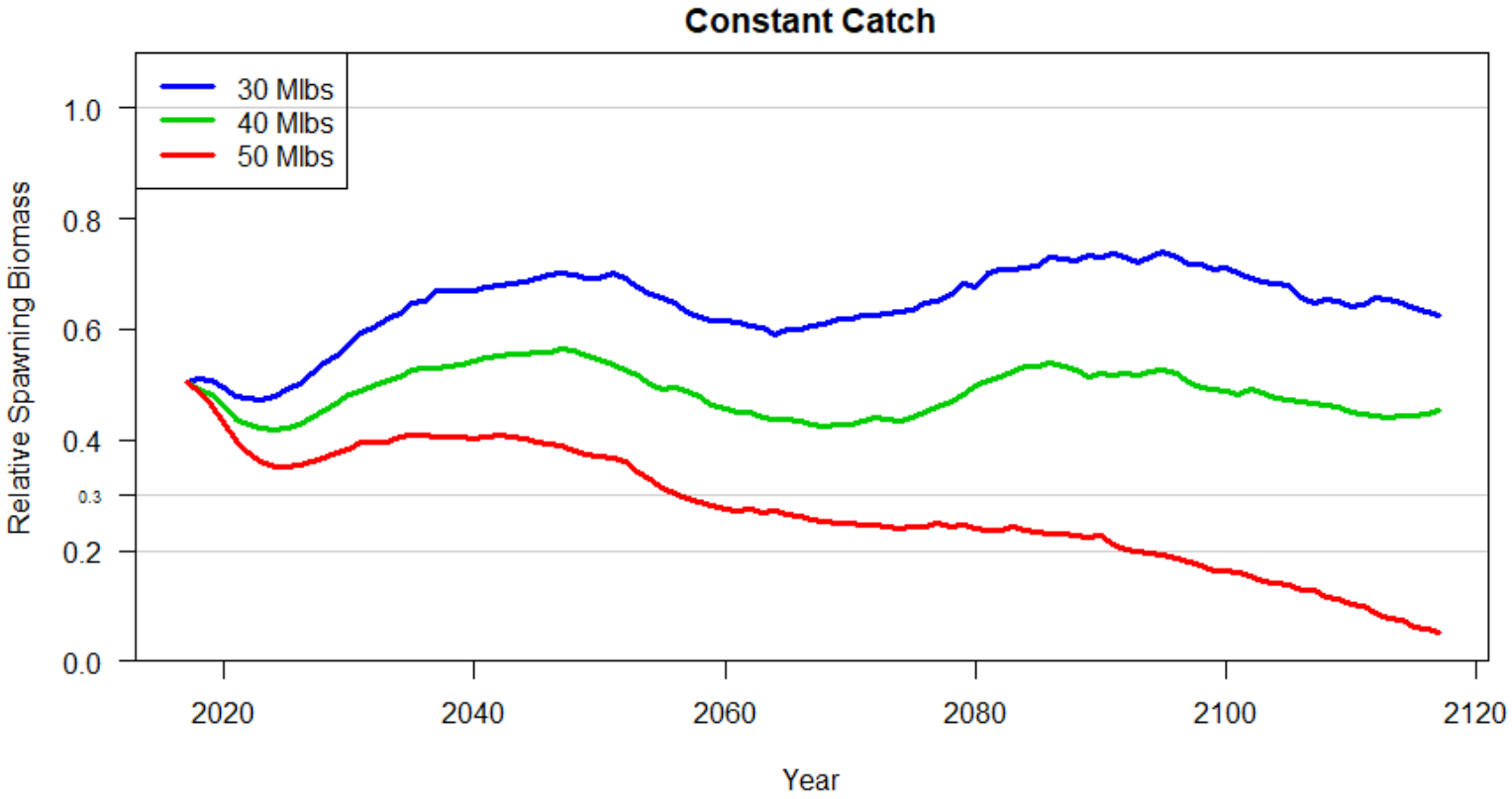
No directed fishing



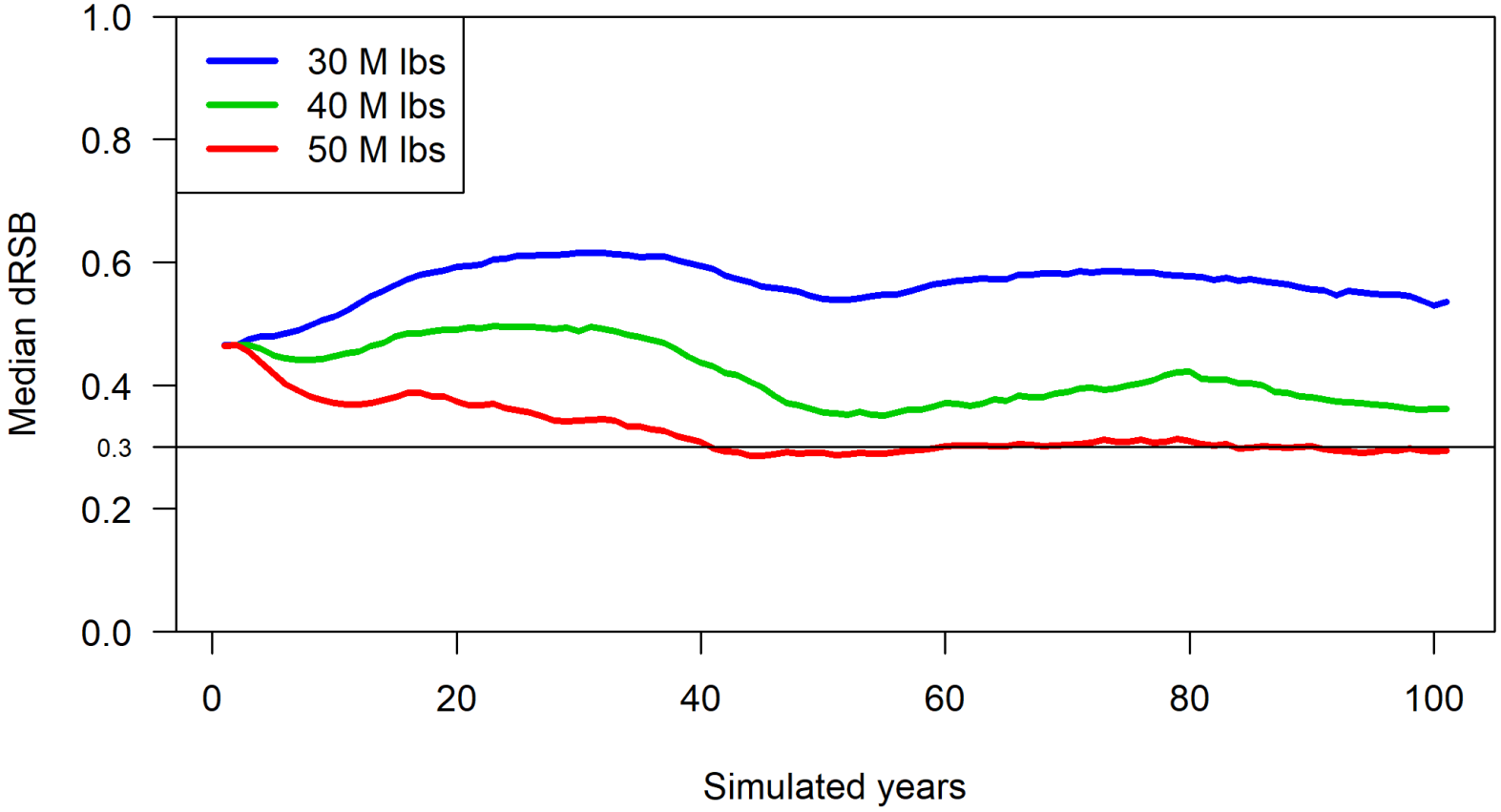
Lessons learned (no fishing simulations)

- Simulations need lots of testing and iteration
  - A temporary hire would be helpful now
  - The simulations appear to work for the population
- The periodicity of weight-at-age and environmental regime maintain some presence for many years
  - Summarize over a wide range of years (40-50)
  - Simulate further in time

Constant Catch without a control rule



Constant Catch with 30:20 control rule



Constant Total Mortality

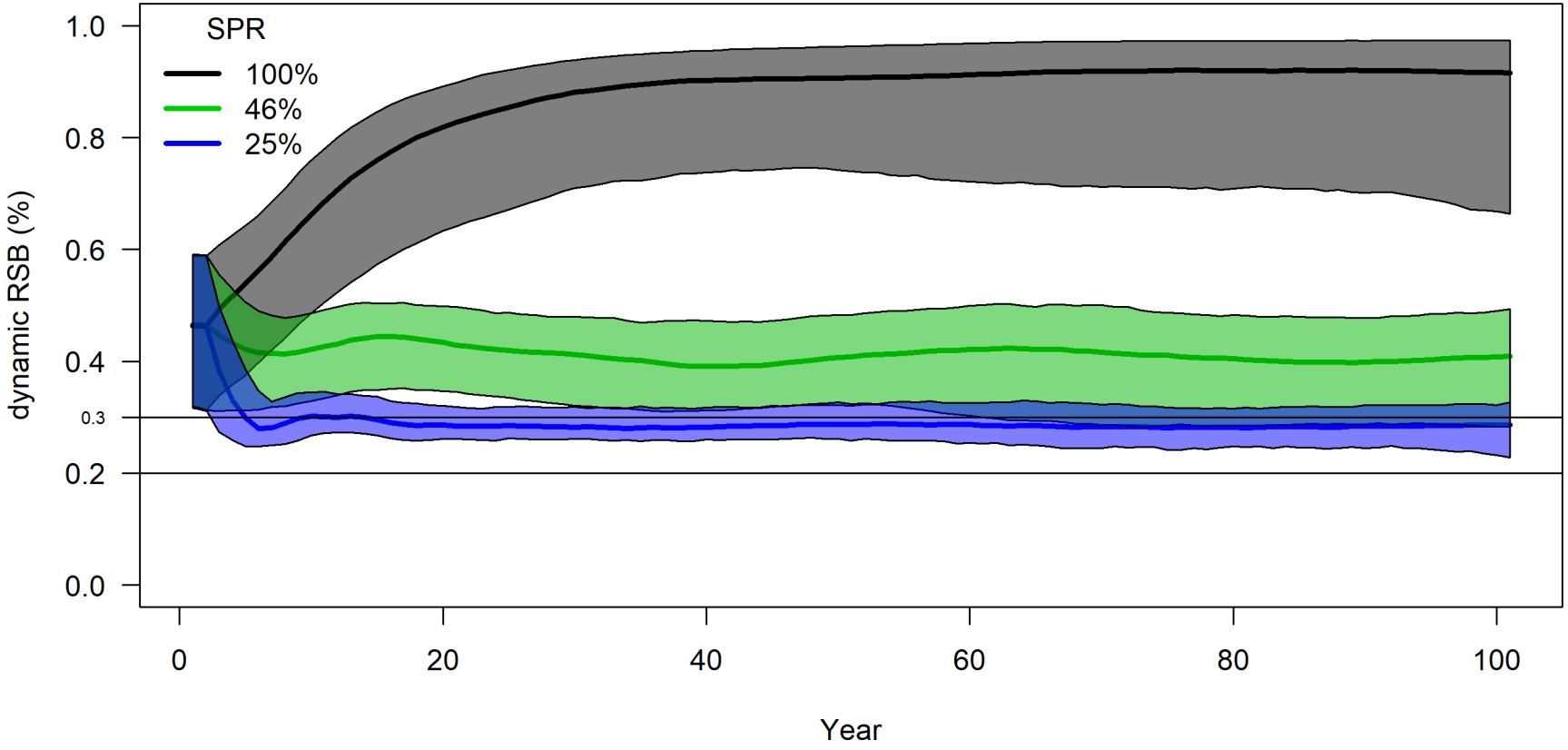
Constant TM (M lbs)	0	30	40	50
Median average SPR	92.6%	57.0%	47.9%	43.6%
Biological Sustainability				
Median average dRSB	91.9%	54.7%	36.7%	29.3%
P(dRSB<20%)	1%	4%	6%	6%
P(dRSB<30%)	1%	29%	42%	51%
Median average # mature females (Mill)	13.69	8.57	6.91	6.61
Fishery Sustainability				
Median average Total Mortality (M lbs)	7.67	30.00	40.00	42.13
Median average Commercial (M lbs)	0.00	15.27	23.68	26.58
P(No Commercial)	100%	9%	11%	12%
P(FCEY < 70% average 1993-2012)	100%	100%	100%	100%
P(decrease TM > 15%)	28%	5%	8%	11%
P(increase TM > 15%)	31%	5%	8%	12%
Median catch variability (AAV)	21.1%	0.0%	0.0%	5.5%

NOTE: THE YIELD DOESN'T ACCOUNT FOR WHETHER OR NOT IT COULD BE TAKEN

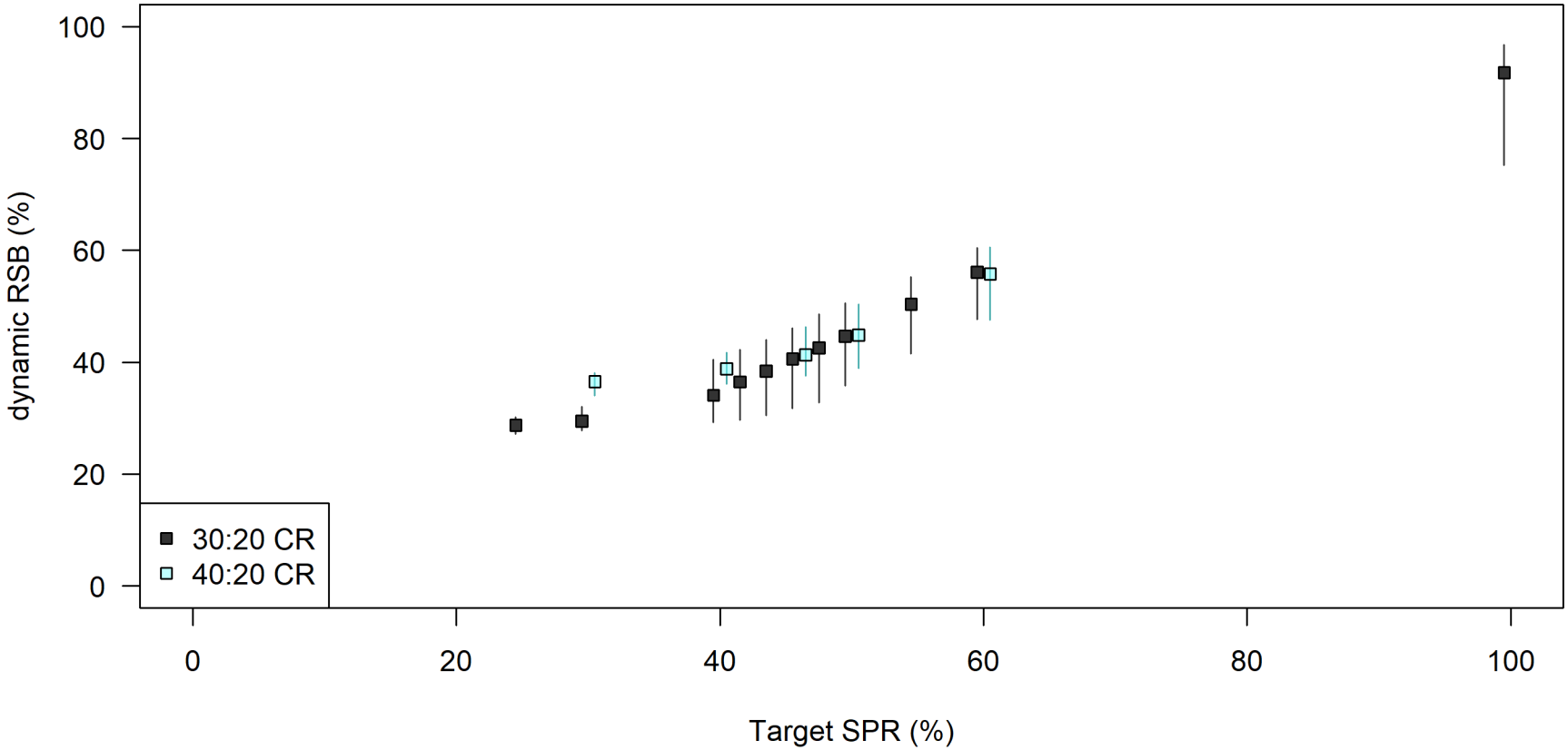
SPR and control rules (design)

Target SPR	Long CW Perfect Information DynamicB0		Short CW Perfect Information DynamicB0	
	CR30:20	CR40:20	CR30:20	CR40:20
100	800		850	
25	750		Blackbox 750	
30	700	700	Blackbox 800	Blackbox 700
40			Blackbox	Blackbox
42	700		Blackbox 700	
44	700		Blackbox 700	
46			Blackbox	Blackbox
48	550		550 Blackbox	
50			Blackbox	Blackbox
55	550	550	Blackbox 750	Blackbox 550
60	500	500	Blackbox 500	Blackbox 500

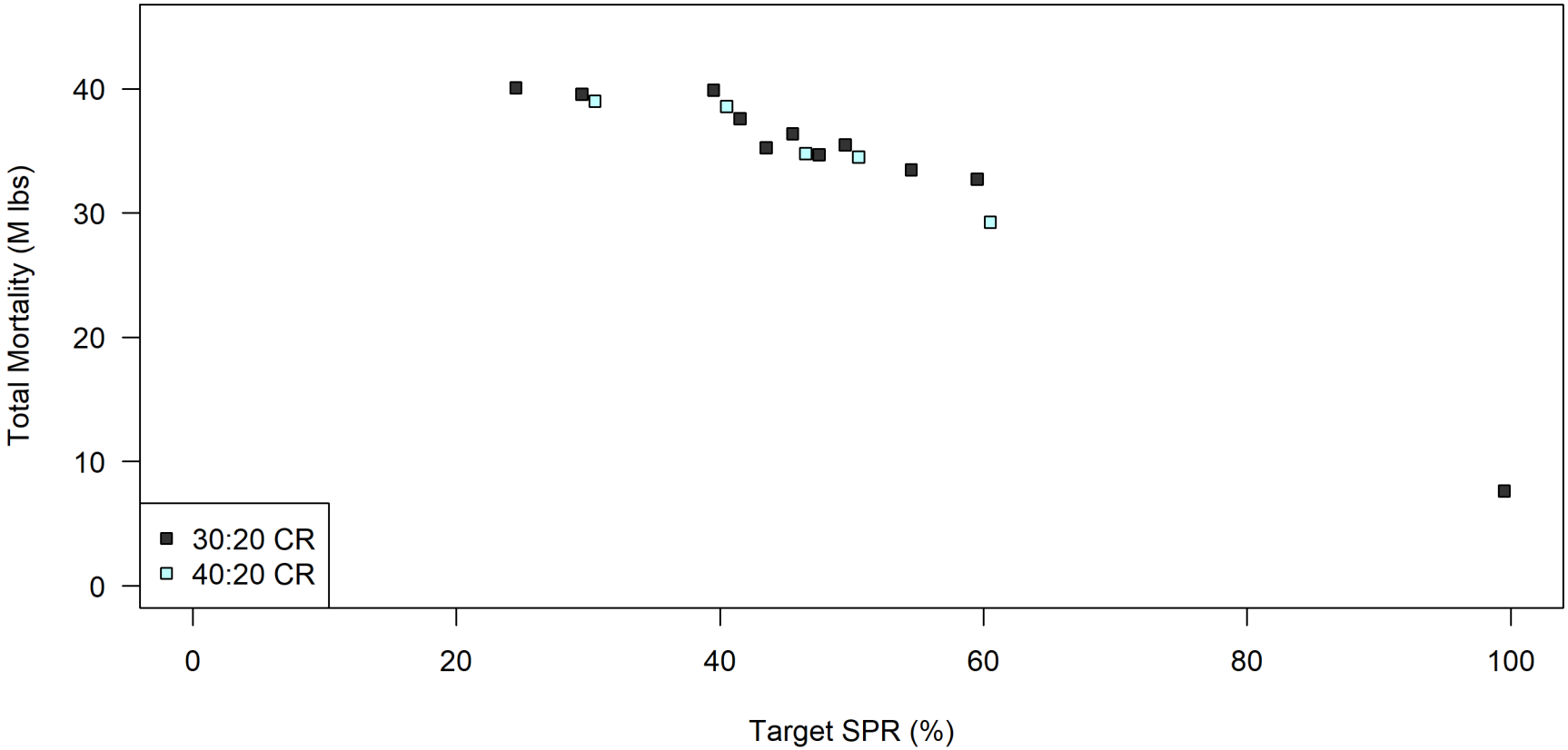
SPR simulations



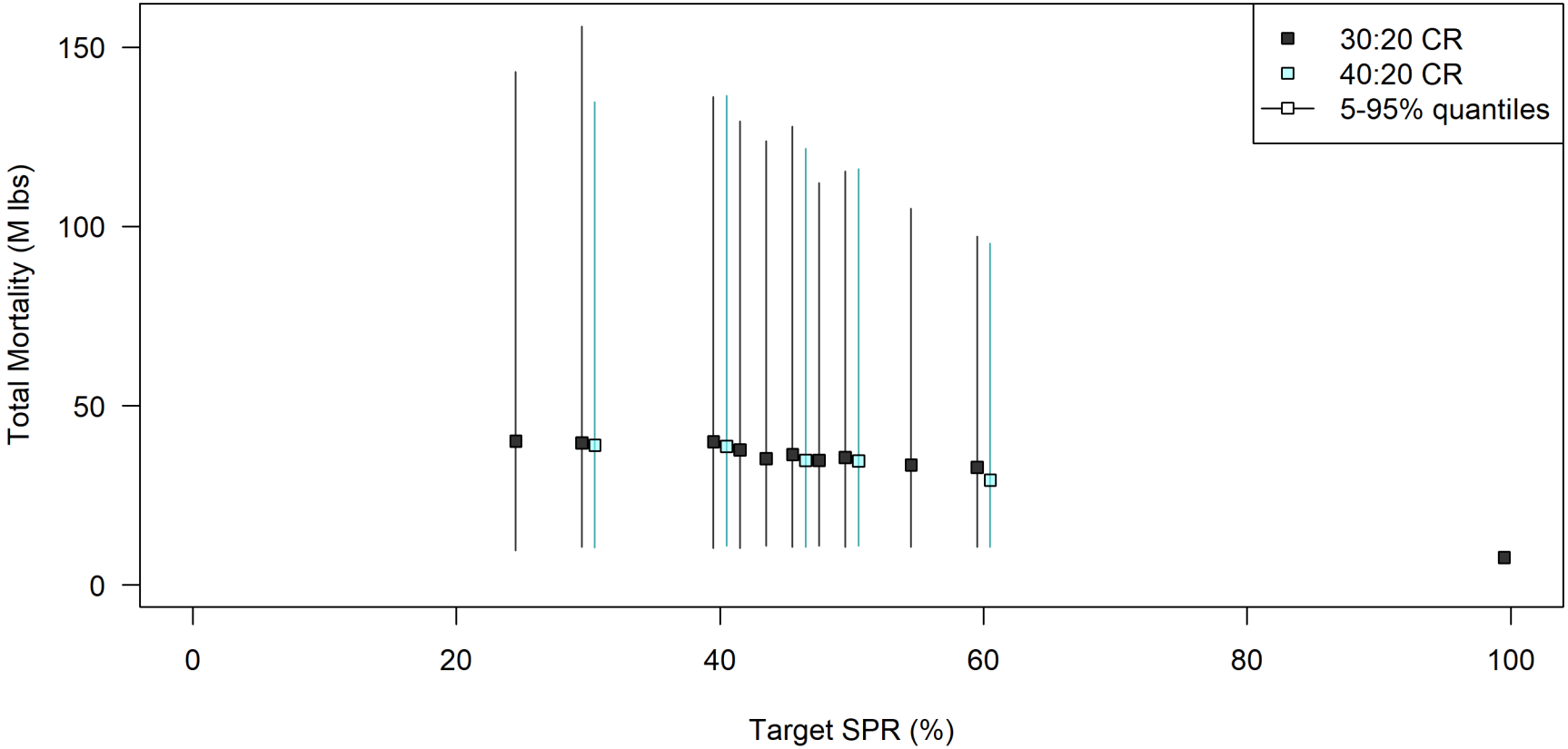
Relative spawning biomass (dynamic)



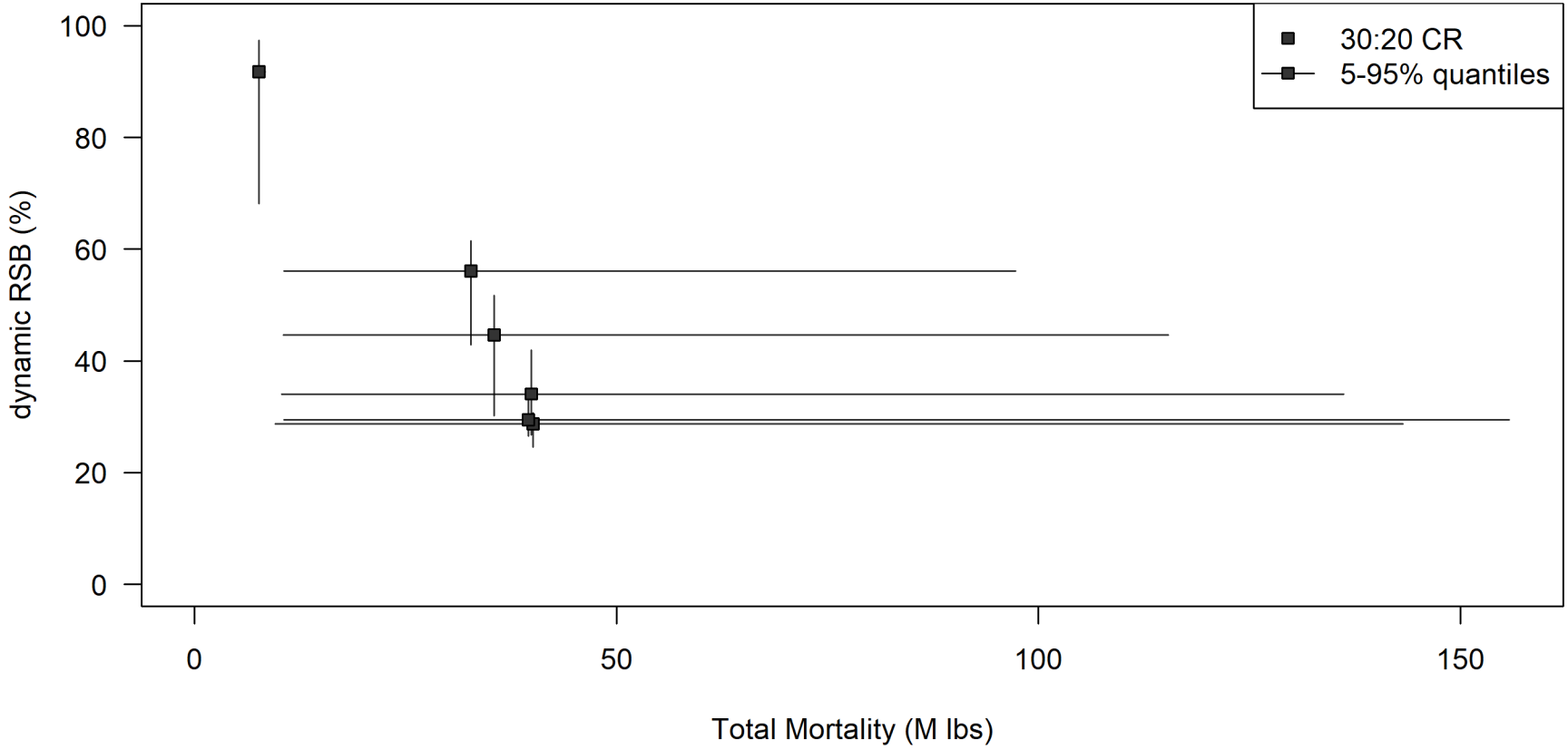
Total mortality



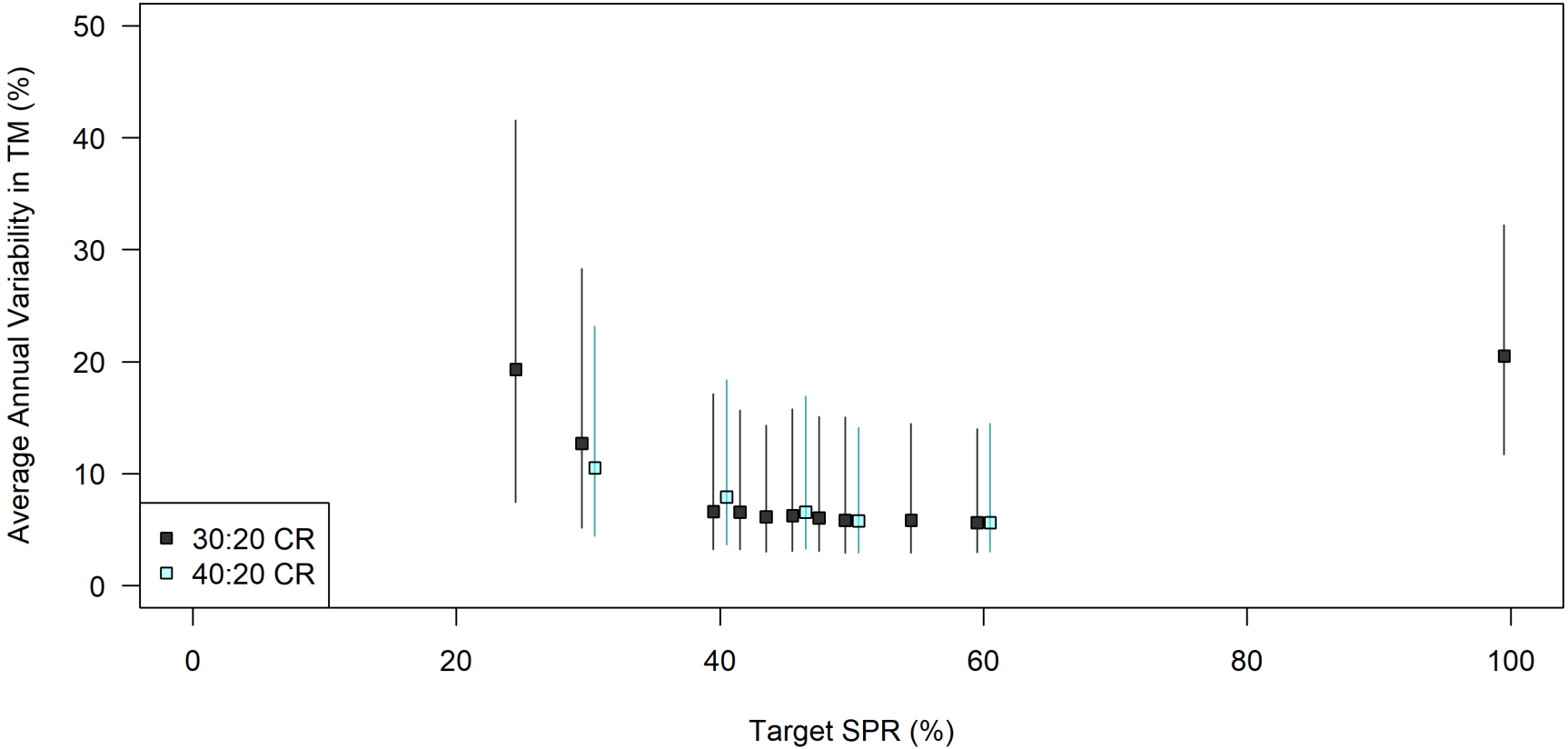
Total mortality with uncertainty



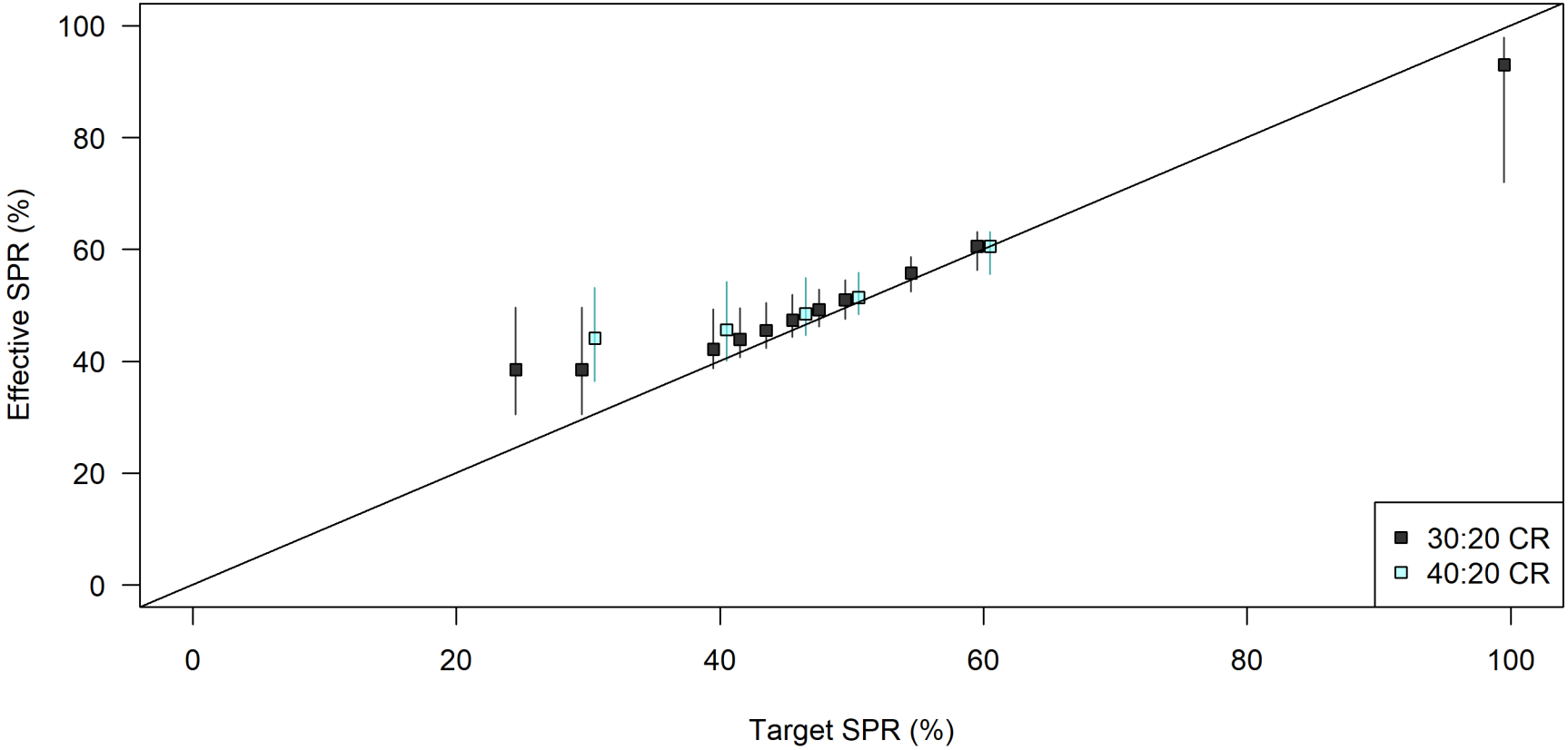
Total mortality and dRSB trade-offs



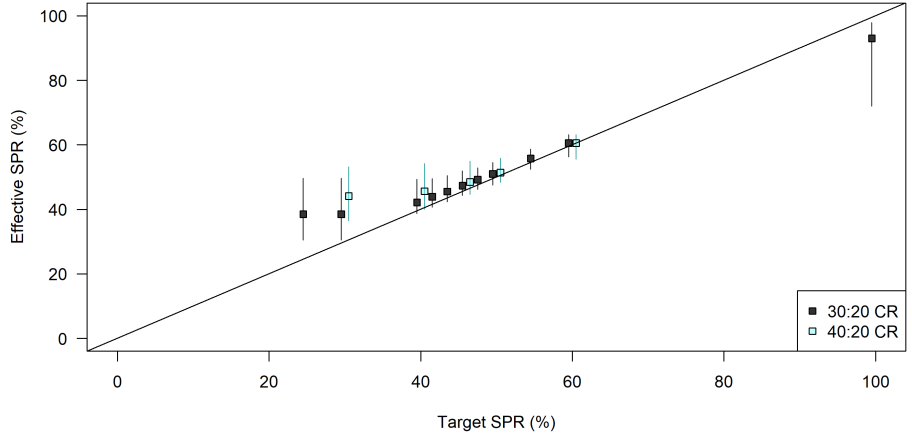
Variability in total mortality (AAV)

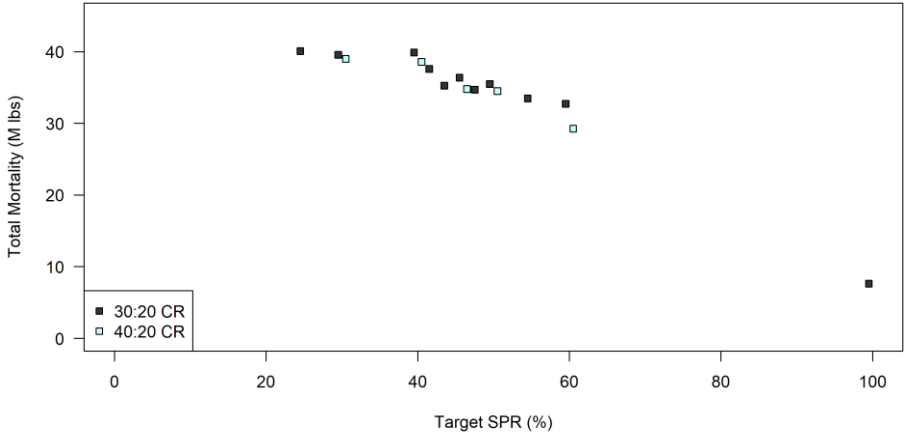


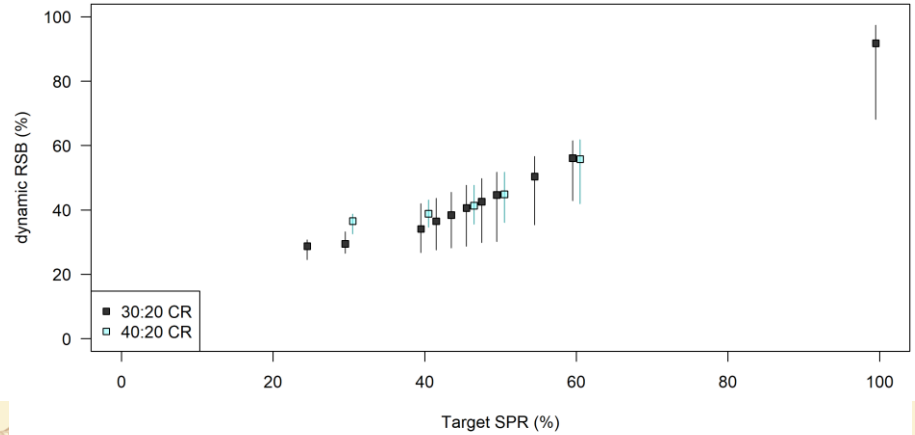
Realized SPR

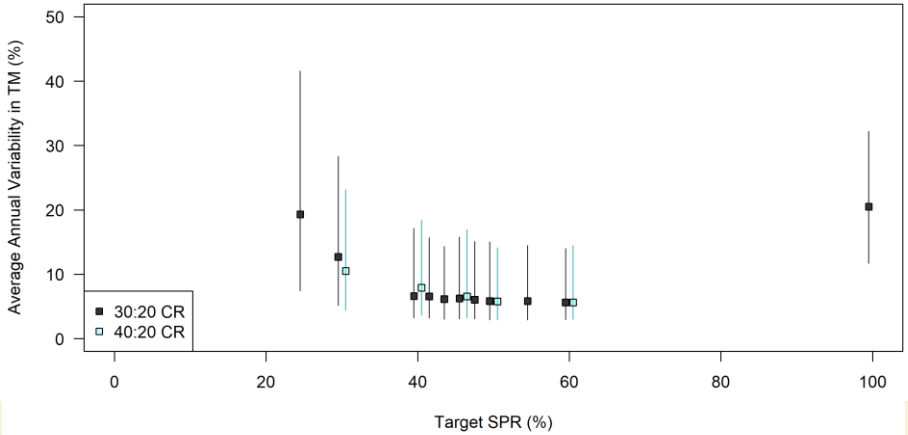


All together now









SPR

30:20 CR

Target SPR (%)	25%	30%	40%	42%	46%	50%	60%	100%
Median average SPR	38.5%	38.5%	42.1%	43.9%	47.3%	51.0%	60.5%	93.1%
Biological Sustainability								
Median average dRSB	28.7%	29.4%	34.1%	36.5%	40.6%	44.6%	56.0%	91.8%
P(dRSB<20%)	3%	3%	3%	2%	2%	2%	1%	0%
P(dRSB<30%)	78%	64%	19%	13%	7%	5%	2%	0%
Median average # mature females (Mill)	5.87	5.97	6.73	6.98	7.59	8.03	9.75	13.63
Fishery Sustainability								
Median average Total Mortality (M lbs)	40.09	39.56	39.91	37.62	36.37	35.50	32.72	7.63
Median average Commercial (M lbs)	24.75	24.32	24.47	22.84	21.24	20.09	17.70	0.00
P(No Commercial)	11%	9%	8%	8%	8%	8%	10%	100%
P(FCEY < 70% average 1993-2012)	68%	66%	68%	68%	72%	73%	79%	100%
P(decrease TM > 15%)	24%	17%	6%	5%	5%	4%	3%	27%
P(increase TM > 15%)	27%	19%	7%	7%	6%	5%	5%	30%
Median catch variability (AAV)	19.3%	12.7%	6.6%	6.6%	6.2%	5.8%	5.6%	20.5%

NOTE: THE YIELD DOESN'T ACCOUNT FOR WHETHER OR NOT IT COULD BE TAKEN

SPR

40:20 CR

Target SPR (%)	30%	40%	46%	50%	60%	100%
Median average SPR	44.1%	45.6%	48.4%	51.4%	60.6%	93.1%
Biological Sustainability						
Median average dRSB	36.5%	38.8%	41.3%	44.9%	55.7%	91.8%
P(dRSB<20%)	1%	1%	1%	2%	1%	0%
P(dRSB<30%)	3%	3%	3%	3%	2%	0%
Median average # mature females (Mill)	6.92	7.38	7.67	8.32	9.60	13.63
Fishery Sustainability						
Median average Total Mortality (M lbs)	39.00	38.57	34.78	34.51	29.27	7.63
Median average Commercial (M lbs)	23.59	23.40	19.66	19.59	15.17	0.00
P(No Commercial)	9%	7%	8%	8%	10%	100%
P(FCEY < 70% average 1993-2012)	67%	68%	72%	72%	80%	100%
P(decrease TM > 15%)	12%	8%	6%	4%	3%	27%
P(increase TM > 15%)	16%	10%	7%	5%	5%	30%
Median catch variability (AAV)	10.5%	7.9%	6.5%	5.8%	5.6%	20.5%

SPR 30:20 CR

Target SPR (%)	30%	40%	50%	60%
Median average SPR	38.5%	42.1%	51.0%	60.5%
Biological Sustainability				
Median average dRSB	29.4%	34.1%	44.6%	56.0%
P(dRSB<20%)	3%	3%	2%	1%
P(dRSB<30%)	64%	19%	5%	2%
Median average # mature females (Mill)	5.97	6.73	8.03	9.75
Fishery Sustainability				
Median average Total Mortality (M lbs)	39.56	39.91	35.50	32.72
Median average Commercial (M lbs)	24.32	24.47	20.09	17.70
P(No Commercial)	9%	8%	8%	10%
P(FCEY < 70% average 1993-2012)	66%	68%	73%	79%
P(decrease TM > 15%)	17%	6%	4%	3%
P(increase TM > 15%)	19%	7%	5%	5%
Median catch variability (AAV)	12.7%	6.6%	5.8%	5.6%

SPR 40:20 CR

30%	40%	50%	60%
44.1%	45.6%	51.4%	60.6%
36.5%	38.8%	44.9%	55.7%
1%	1%	2%	1%
3%	3%	3%	2%
6.92	7.38	8.32	9.60
39.00	38.57	34.51	29.27
23.59	23.40	19.59	15.17
9%	7%	8%	10%
67%	68%	72%	80%
12%	8%	4%	3%
16%	10%	5%	5%
10.5%	7.9%	5.8%	5.6%

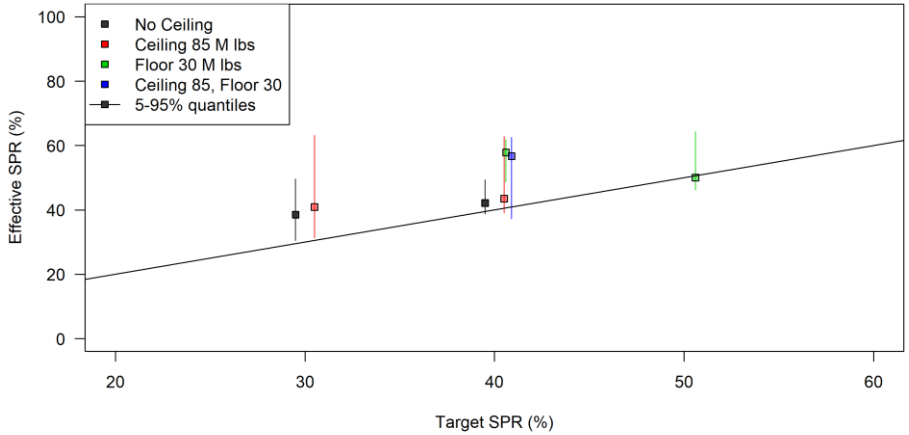
Floor and ceiling on TM

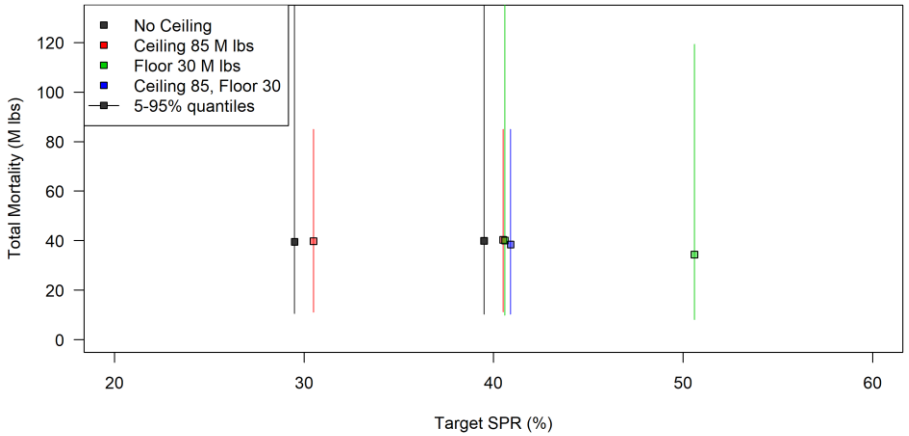
- Maximum TM of 85 Mlbs
- Minimum TM of 30 M lbs
- Min and Max of 30 and 85 M lbs

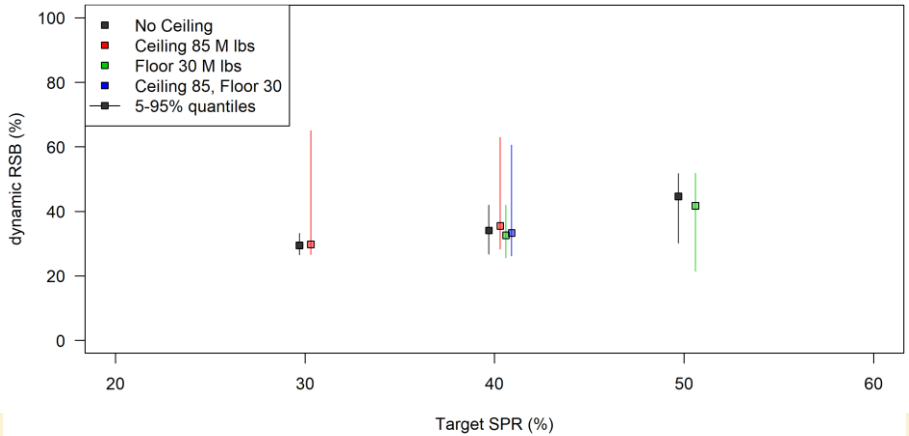
Control rule was applied after the minimum was applied

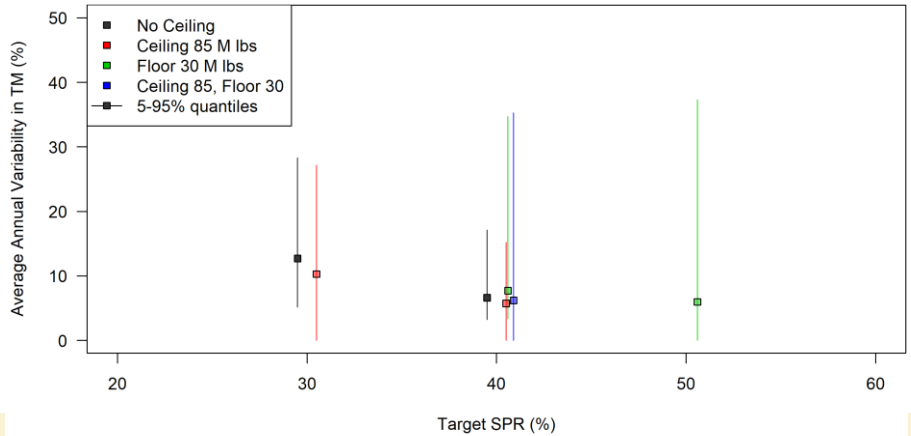
- The adjusted SPR was used to set TM when dRSB<30%

Max TM of 85 and/or Min of 30 M lbs









SPR 30:20 CR

Target SPR (%)	30%	40%	50%
Median average SPR	38.5%	42.1%	51.0%
Biological Sustainability			
Median average dRSB	29.4%	34.1%	44.6%
P(dRSB<20%)	3%	3%	2%
P(dRSB<30%)	64%	19%	5%
Median average # mature females (Mill)	5.97	6.73	8.03
Fishery Sustainability			
Median average Total Mortality (M lbs)	39.56	39.91	35.50
Median average Commercial (M lbs)	24.32	24.47	20.09
P(No Commercial)	9%	8%	8%
P(FCEY < 70% average 1993-2012)	66%	68%	73%
P(decrease TM > 15%)	17%	6%	4%
P(increase TM > 15%)	19%	7%	5%
Median catch variability (AAV)	12.7%	6.6%	5.8%

SPR 30:20 Max TM 85

30%	40%	50%
40.9%	43.5%	
29.7%	35.5%	
3%	1%	
54%	15%	
6.15	7.10	
39.83	40.26	
24.57	24.97	
9%	7%	
64%	65%	
13%	5%	
15%	5%	
10.3%	5.7%	

SPR 30:20 CR

Target SPR (%)	30%	40%	50%
Median average SPR	38.5%	42.1%	51.0%
Biological Sustainability			
Median average dRSB	29.4%	34.1%	44.6%
P(dRSB<20%)	3%	3%	2%
P(dRSB<30%)	64%	19%	5%
Median average # mature females (Mill)	5.97	6.73	8.03
Fishery Sustainability			
Median average Total Mortality (M lbs)	39.56	39.91	35.50
Median average Commercial (M lbs)	24.32	24.47	20.09
P(No Commercial)	9%	8%	8%
P(FCEY < 70% average 1993-2012)	66%	68%	73%
P(decrease TM > 15%)	17%	6%	4%
P(increase TM > 15%)	19%	7%	5%
Median catch variability (AAV)	12.7%	6.6%	5.8%

SPR 30:20 Min TM 30

	30%	40%	50%
		42.1%	49.9%
		32.6%	41.7%
		3%	5%
		29%	23%
		6.74	7.39
		40.09	34.41
		24.50	19.44
		12%	17%
		66%	72%
		10%	8%
		12%	10%
		7.7%	6.0%

SPR 30:20 CR

Target SPR (%)	30%	40%	50%
Median average SPR	38.5%	42.1%	51.0%
Biological Sustainability			
Median average dRSB	29.4%	34.1%	44.6%
P(dRSB<20%)	3%	3%	2%
P(dRSB<30%)	64%	19%	5%
Median average # mature females (Mill)	5.97	6.73	8.03
Fishery Sustainability			
Median average Total Mortality (M lbs)	39.56	39.91	35.50
Median average Commercial (M lbs)	24.32	24.47	20.09
P(No Commercial)	9%	8%	8%
P(FCEY < 70% average 1993-2012)	66%	68%	73%
P(decrease TM > 15%)	17%	6%	4%
P(increase TM > 15%)	19%	7%	5%
Median catch variability (AAV)	12.7%	6.6%	5.8%

SPR 30:20 Max 85, Min 30

30%	40%	50%
	43.3%	
	33.3%	
	3%	
	28%	
	6.73	
	38.37	
	22.64	
	12%	
	67%	
	9%	
	10%	
	6.2%	

Short Coastwide OM

- Is built in a way that requires careful attention
  - Recruitment is freely estimated
- A short time period that is useful to predict short-term ternds, but may not indicate long-term trends
- I need to put some more work into conditioning the model

Sensitivities

- Low and High states of weight-at-age
  - Limited simulated weight-at-age to lower half and upper half of range
  - Not sure if it worked
  - But, at high weight-at-age, median average TM is about double
- Low and High states of recruitment
  - Did not finish this

Sensitivities

- Bycatch selectivity shifted to smaller halibut
  - Did not finish this
- Bycatch a per area maximums
  - Did not finish this
  - The simulated range of bycatch exceeded per area caps

Short-term metrics

- The MSE model does not provide a precise prediction of short-term
  - Designed to provide a robust evaluation of potential scenarios in the long-term
- The assessment model is a precise prediction of the short-term
  - Not representative of the possible range of states in the long-term

Final decision table for 2017 (last AM)

Final decision table of 2017 yield alternatives (rows) and risk metrics (columns). Values in the table represent the probability, in "times out of 100" of a particular risk.

				Stock Trend				Stock Status			
				Spawning biomass				Spawning biomass			
				in 2018		in 2020		in 2018		in 2020	
2017 Alternative	Total removals (M lb)	Fishery CEY (M lb)	Fishing intensity	is less than 2017	is 5% less than 2017	is less than 2017	is 5% less than 2017	is less than 30%	is less than 20%	is less than 30%	is less than 20%
No removals	0.0	0.0	$F_{100\%}$	<1	<1	<1	<1	3	<1	1	<1
FCEY = 0	11.2	0.0	$F_{77\%}$ 61%-84%	1	<1	3	<1	3	<1	1	<1
	20.0	8.6	$F_{66\%}$ 49%-75%	5	<1	20	4	4	<1	3	<1
	30.0	18.4	$F_{55\%}$ 39%-67%	32	<1	53	31	5	<1	6	<1
	37.9	26.1	$F_{48\%}$ 33%-62%	56	3	77	53	6	<1	12	<1
status quo SPR	41.6	29.7	$F_{46\%}$ 32%-60%	68	6	87	64	6	<1	15	<1
Adopted	43.3	31.4	$F_{45\%}$ 30%-59%	71	10	89	67	6	<1	17	<1
	50.0	37.9	$F_{40\%}$ 27%-55%	92	29	98	88	7	<1	25	1
	60.0	47.7	$F_{35\%}$ 23%-51%	>99	52	>99	99	9	<1	37	3
				a	b	c	d	e	f	g	h

Short-term metrics

- Use the decision table from the assessment model to understand the short-term trends
  - Maybe suggest a few management procedures to include in the decision table

Medium-term metrics

- It is more difficult than short-term and medium-term
  - Short-term (3 years) is not creating electronic fish
  - Long-term is integrating over all possible states
  - Medium-term is creating electronic fish, but also narrowing down the possible states
- We need to develop a tool that can provide some advice

All long-term metrics

See PerformanceMetrics_201710.xlsx

Some things to consider

- Simulation framework and assumptions
  - Conditioning & adding uncertainty to the OM
  - Simulation of
    - Weight-at-age
    - Environmental regime
  - Allocating TM to sectors
- Long-term results

More things to recommend

- Enhancements to the simulation framework
- Modifications to assumptions
- Management procedure(s) that would meet the goals and objectives
- Recommend a management procedure to update the IPHC interim harvest strategy
  - Or continue to use the interim status quo harvest strategy

Additional requests

- For tomorrow
  - Summarize simulations differently for tomorrow
  - Other performance metrics
  - Other plots
  - Sleep?
- For 2018
  - Additional management procedures related to scale
  - We'll talk about the workplan on Thursday