INTERNATIONAL PACIFIC HALIBUT COMMISSION

Management Strategy Evaluation Update

Agenda Item 6

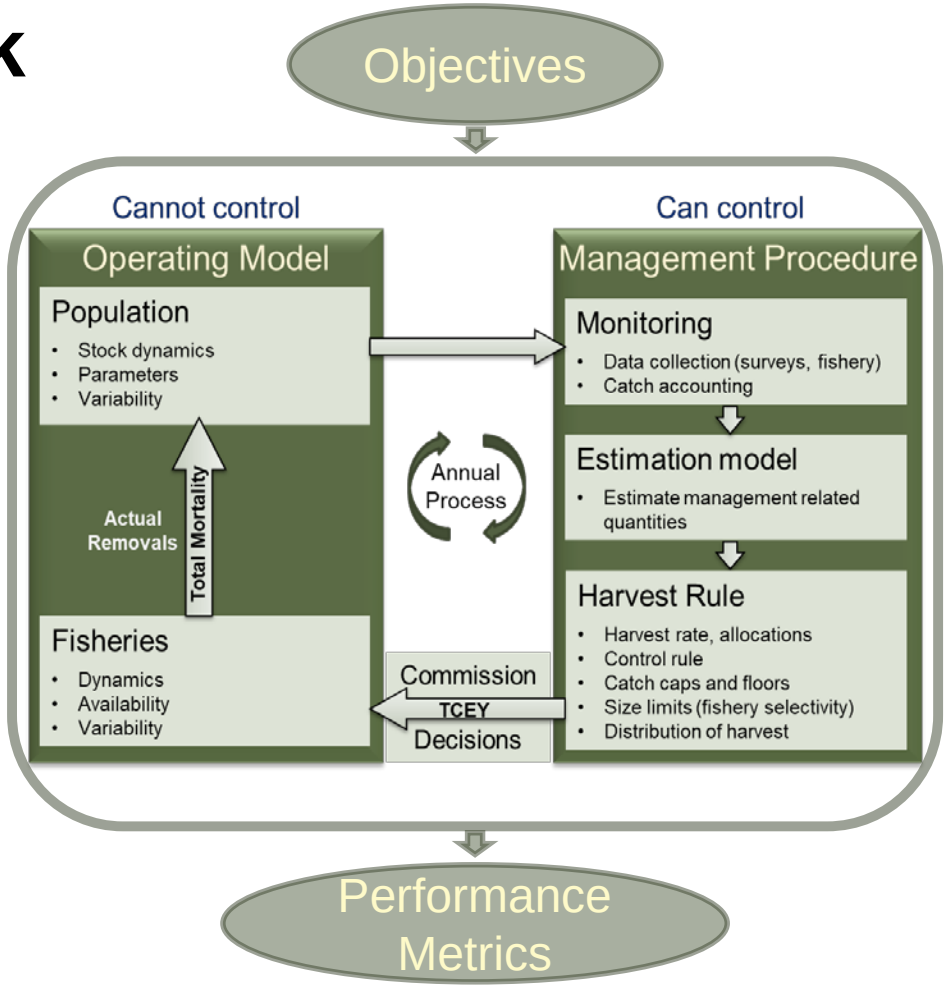
IPHC-2020-SRB016-08 Rev_1

Program of Work

May 2020 MSAB Meeting (MSAB015)	Progress
Review Goals and Objectives (Distribution & Scale)	Completed
Review simulation framework	Completed
Review multi-area model	Completed
Review preliminary results	
Identify MPs (Distribution & Scale)	Completed
June 2020 SRB Meeting (SRB016)	
Review simulation framework	
Review multi-area model	
Review preliminary results	
August 2020 MSAB Special Session	
Evaluate preliminary results	
September 2020 SRB Meeting (SRB017)	
Review penultimate results	
October 2020 MSAB Meeting (MSAB016)	
Review final results	
Provide recommendations on MPs for scale and distribution	
Annual Meeting 2021	
Presentation of first complete MSE product to the Commission Recommendations on Scale and Distribution MP	

Simulation Framework

- The framework contains
  - The elements of the closed-loop simulations
  - The input of objectives and output of performance metrics



General Objectives

- Primary biological objectives
- Primary fishery objectives
  - Target Spawning Biomass to optimise fishing activities
  - Stability in mortality limits
  - Provide directed fishing yield

MSAB014: https://www.iphc.int/uploads/pdf/msab/msab014/iphc-2019-msab014-r.pdf

Commission: https://iphc.int/uploads/pdf/cir/2020/iphc-2020-cr-007.pdf

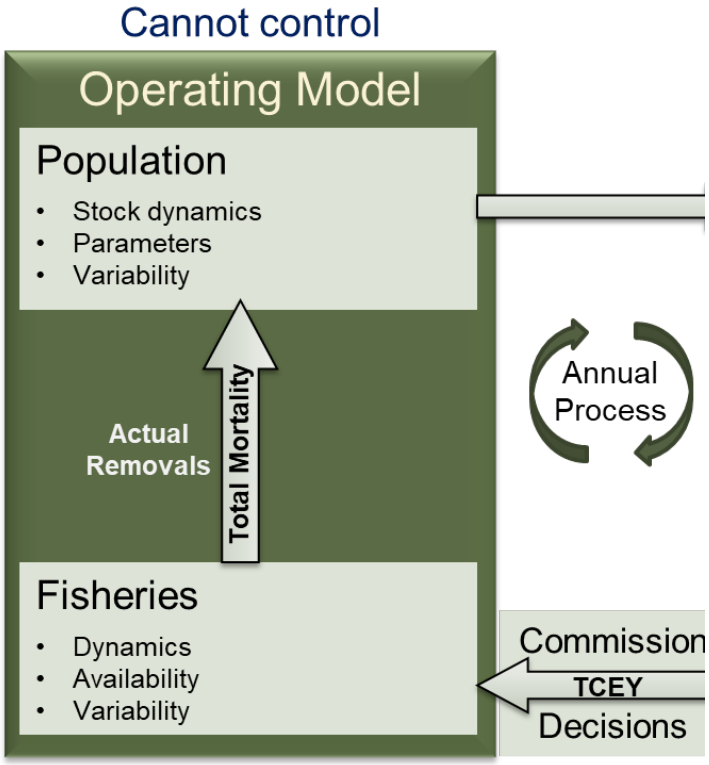
Simulation framework specifications

- An interaction of C++ and R
- Operating Model (OM) written in C++
  - Fast and generalized
  - JSON input files
  - Many output formats
- Management Procedures (MP) written in R
  - Quick and simple implementation of MPs

Workflow options in simulation framework

- Closed-loop simulation
  1. OM calls R scripts for application of the MP
  2. OM called from R and restarted at the previous state
  3. OM self-sufficient for simple MPs
  4. OM and MPs are one executable (in development)

Operating Model (OM)



For technical details, see:

https://www.iphc.int/venues/details/16th-session-of-the-iphc-scientific-review-board-srb016

MSAB015 Report

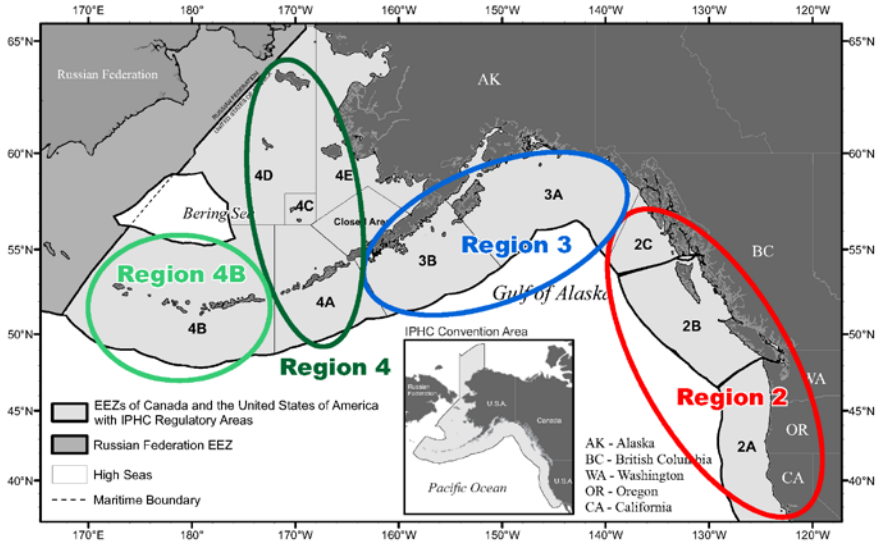
https://www.iphc.int/uploads/pdf/msab/msab015/iphc-2020-msab015-r.pdf

Generalized operating model

- Multi-area
- Two-sex
- Age-, sex-, time-, and area-specific parameters
- Fisheries specific to area
  - Fisheries occur sequentially according to specified timing
- Population initialized with
  - multiple iterations without fishing followed by a
  - specified initial period with rec devs & constant fishing mortality
- Dynamic unfished population calculated separately from the fished population

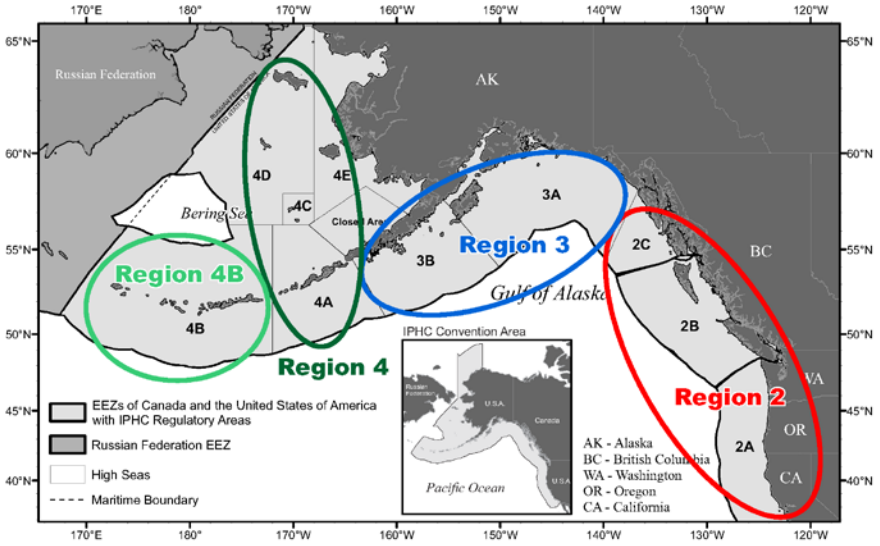
OM specifications: Regions

- Four Biological Regions to model biological processes
  - Movement
  - Natural mortality
  - Size-at-age
  - Recruitment



OM specifications: Areas

- Eight IPHC Regulatory Areas for fisheries
- An area is completely within a Region



OM specifications: Fishing Sectors

- Five sectors
  1. Directed commercial fishery
     - O32 mortality from directed fisheries
  2. Directed commercial discard mortality (*directed discards*)
     - U32 mortality from directed fisheries
  3. Non-directed commercial discard mortality (*non-directed*)
     - Mortality from non-directed fisheries
  4. Recreational
     - Mortality from recreational landings and discards
  5. Subsistence
     - Mortality from non-commercial, customary and traditional use

OM specifications: Fisheries

- A fishery is a specific sector within an IPHC Regulatory Area or Biological Region

Summed mortality (1992-2019) by sector and area (i.e., fishery)

Year	2A	2B	2C	3A	3B	4A	4CDE	4B
Commercial	18	260	206	552	252	78	73	63
Sublegal discards	<1	7	5	17	11	2	1	<1
Non-directed	12	12	5	74	36	39	16	129
Recreational	14	32	71	152	<1	1	<0.1	<0.1
Subsistence	<1	10	10	8	1	<1	<0.1	2

OM specifications: 33 Fisheries

Fishery	IPHC Reg Areas	2019 Mortality
Directed Commercial 2A	2A	0.89
Directed Commercial 2B	2B	5.22
Directed Commercial 2C	2C	3.67
Directed Commercial 3A	3A	8.16
Directed Commercial 3B	3B	2.31
Directed Commercial 4A	4A	1.45
Directed Commercial 4B	4B	1.00
Directed Commercial 4CDE	4CDE	1.65

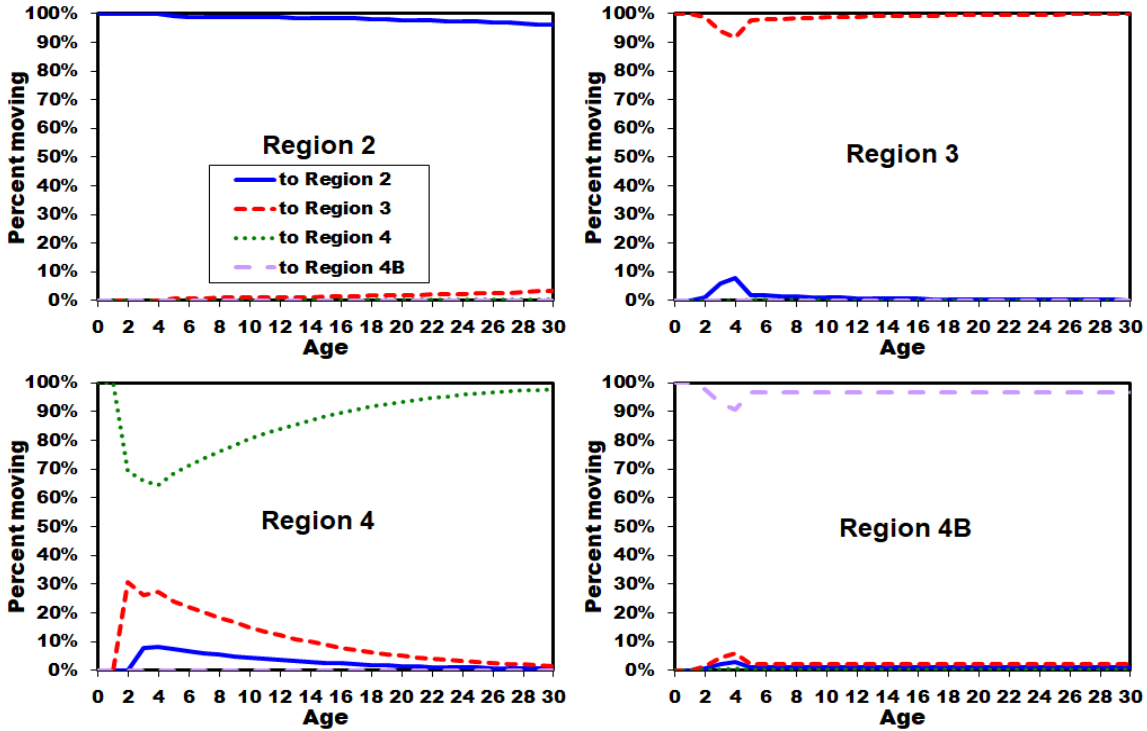
Fishery	IPHC Reg Areas	2019 Mortality
Directed Commercial Discards 2A	2A	0.03
Directed Commercial Discards 2B	2B	0.13
Directed Commercial Discards 2C	2C	0.06
Directed Commercial Discards 3A	3A	0.32
Directed Commercial Discards 3B	3B	0.15
Directed Commercial Discards 4A	4A	0.09
Directed Commercial Discards 4B	4B	0.03
Directed Commercial Discards 4CDE	4CDE	0.07

Fishery	IPHC Reg Areas	2019 Mortality
Non-Directed Comm Discards 2A	2A	0.13
Non-Directed Comm Discards 2B	2B	0.24
Non-Directed Comm Discards 2C	2C	0.09
Non-Directed Comm Discards 3A	3A	1.65
Non-Directed Comm Discards 3B	3B	0.48
Non-Directed Comm Discards 4A	4A	0.35
Non-Directed Comm Discards 4B	4B	0.15
Non-Directed Comm Discards 4CDE	4CDE	3.5

Fishery	IPHC Reg Areas	2019 Mortality
Recreational 2B	2B	0.86
Recreational 2C	2C	1.89
Recreational 3A	3A	3.69
Subsistence 2B	2B	0.41
Subsistence 2C	2C	0.37
Subsistence 3A	3A	0.19
Recreational/Subsistence 2A	2A	0.48
Recreational/Subsistence 3B	3B	0.02
Recreational/Subsistence 4	4A,4CDE	0.06

Movement

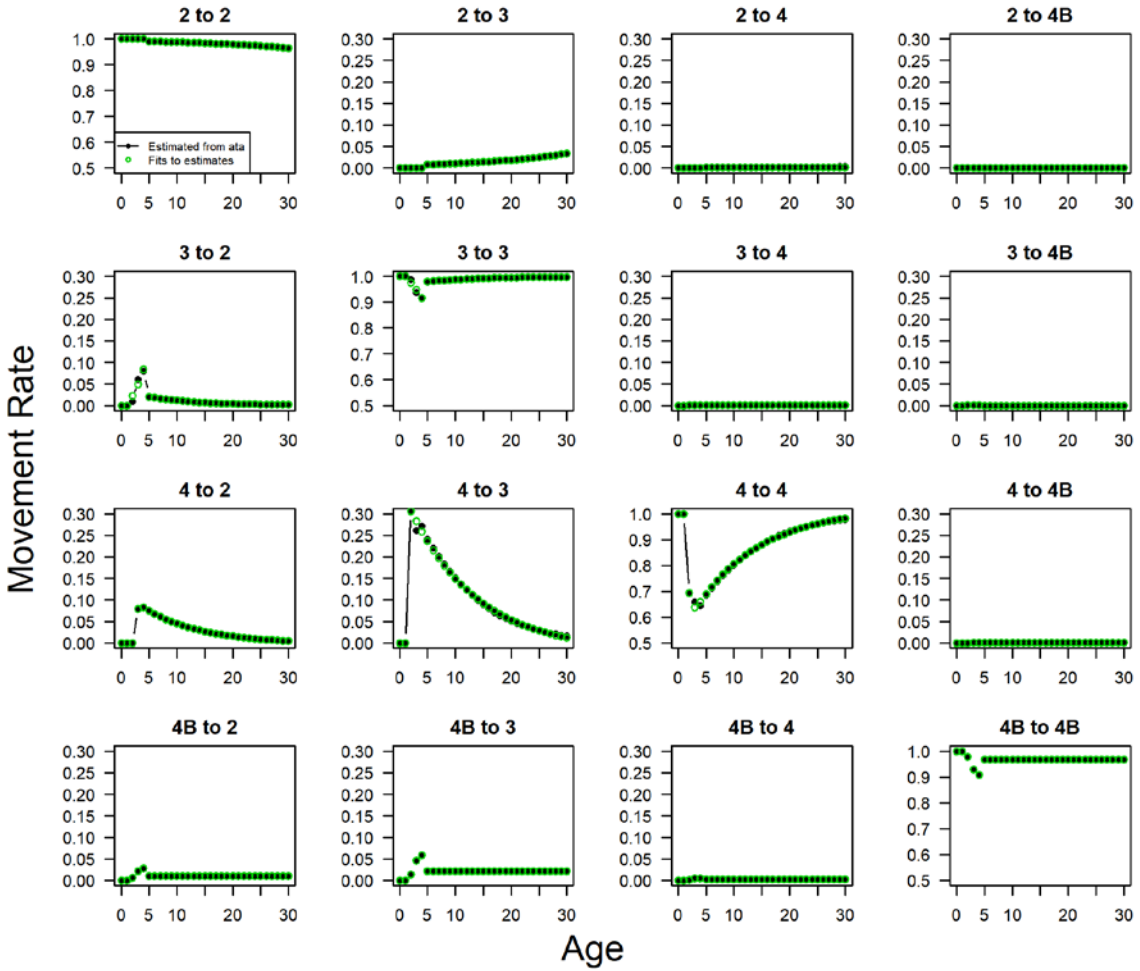
- Integration of information from many sources
  - Recent review of halibut movement
  - Estimated annual movement rates
  - Tuned to observations



Estimated aggregate annual movement rates by age from Biological Regions (panels) based on currently available data

Movement in the OM

- Four functional forms
  1. Constant
  2. Exponential
  3. Double exponential
  4. Values

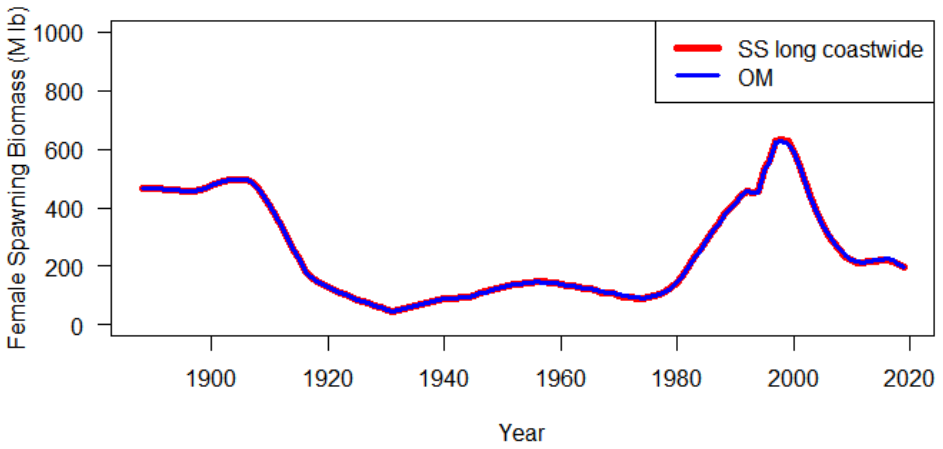


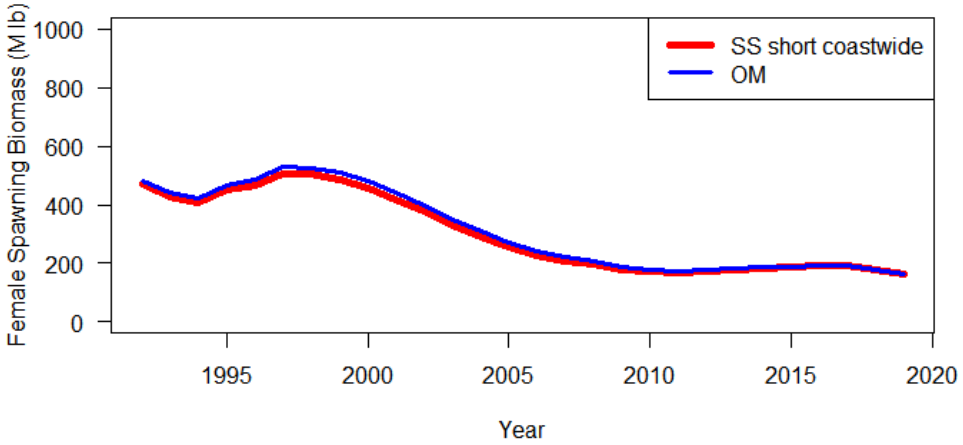
Verification of the operating model code

- Confirming that the calculations are correct and that the outcomes follow the appropriate fishery and population dynamics as intended
  - Compare outputs with simple models
  - Compare outputs with complex models (e.g. assessment)
  - Verify it returns to appropriate values without fishing

Conditioned models

- Assessment models use stock synthesis
- Some different assumptions in the OM
- Very similar trajectories well within uncertainty intervals





Uncertainty and variability

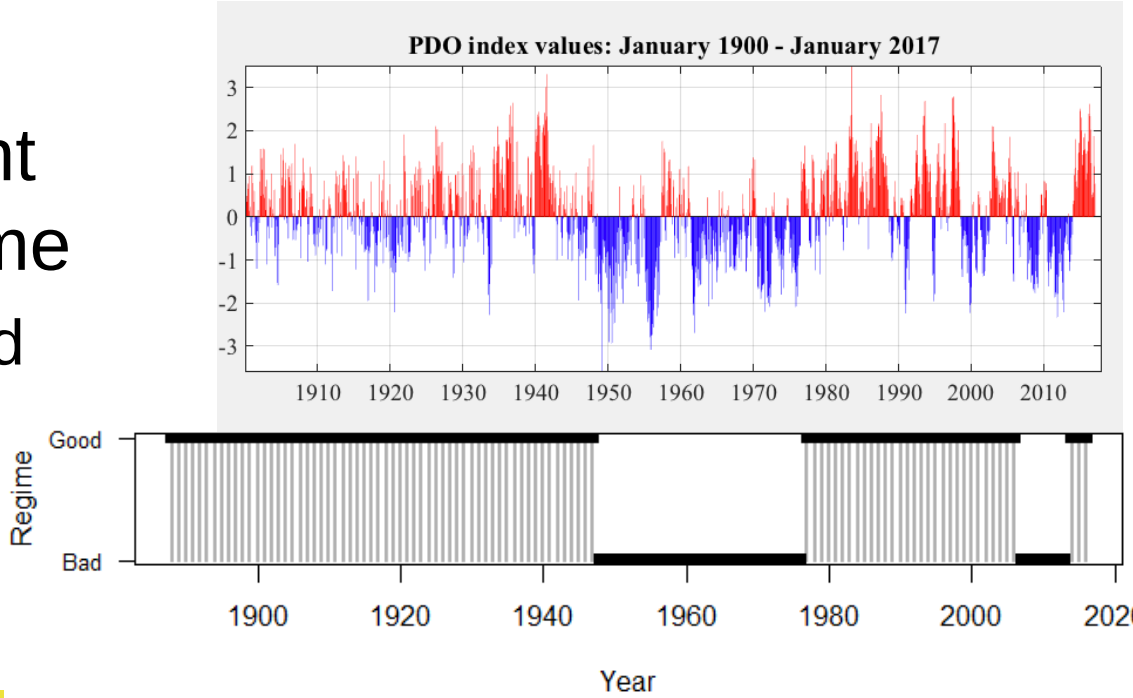
1. Integrated uncertainty
   - Uncertain parameters
     - M, steepness, R_0, movement, selectivity parameters
   - Variability in projections
     - selectivity, weight-at-age, recruitment, movement
2. Scenarios
   - Specific case to investigate departure in an assumption
     - Weight-at-age at a specified level
     - Non-directed mortality at a specific amount
     - Movement
   - May or may not be integrated into results

Uncertainty and variability

Process	Uncertainty
Natural Mortality (M)	Estimate appropriate uncertainty when conditioning OM
Steepness	Estimate appropriate uncertainty when conditioning OM
Recruitment	Random, lognormal deviations
Size-at-age	Annual and cohort deviations in weight-at-age with bounds
Regime Shifts	Autocorrelated indicator based on properties of the PDO for regime shift
Sector mortality	Allocating mortality to sectors within an area
Selectivity	Directed fishery and survey selectivity projections
Implementation	Implementation variability (annual mortality and decisions)
Movement	To be determined

Recruitment variability

- Annual deviations from average recruitment
- Average recruitment dependent on regime
  - Regime is simulated as a random process
    - High or low



Weight-at-age variability

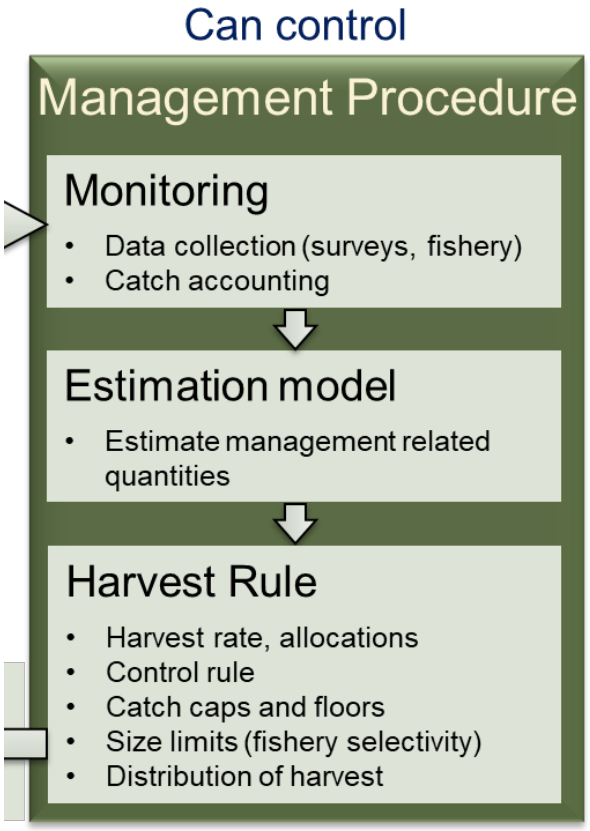
- New method for projecting weight-at-age
- Two types of deviations
  1. Deviations consistent across regions and ages
     - ARIMA model uses previous three years to project the next year
  2. Deviations independent of regions and ages
     - Random

Implementation variability

1. Decision-making
   – Adopted TCEYs may depart from the MP outcomes
2. Actual fishing mortality
   – Fisheries do not exactly catch the set limit
3. Uncertainty in the estimated amount of variability

- Will look at past observations to determine reasonable methods

Management Procedures

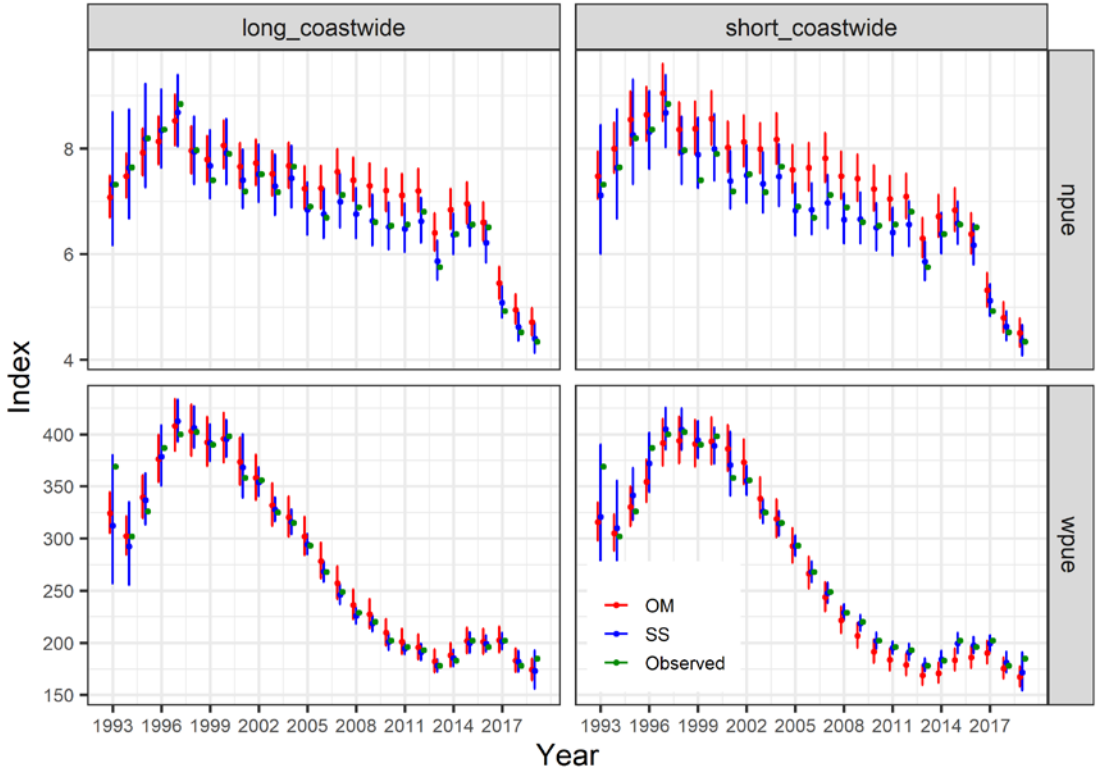


Monitoring

- Data generated with error from the OM
  - Indices of abundance (Lognormal)
    - survey NPUE & commercial WPUE
  - Catch-at-age proportions (Dirichlet)
- Data generated for each Biological Region
  - Aggregated to coastwide appropriately
  - Split to IPHC Regulatory Area with assumed proportions

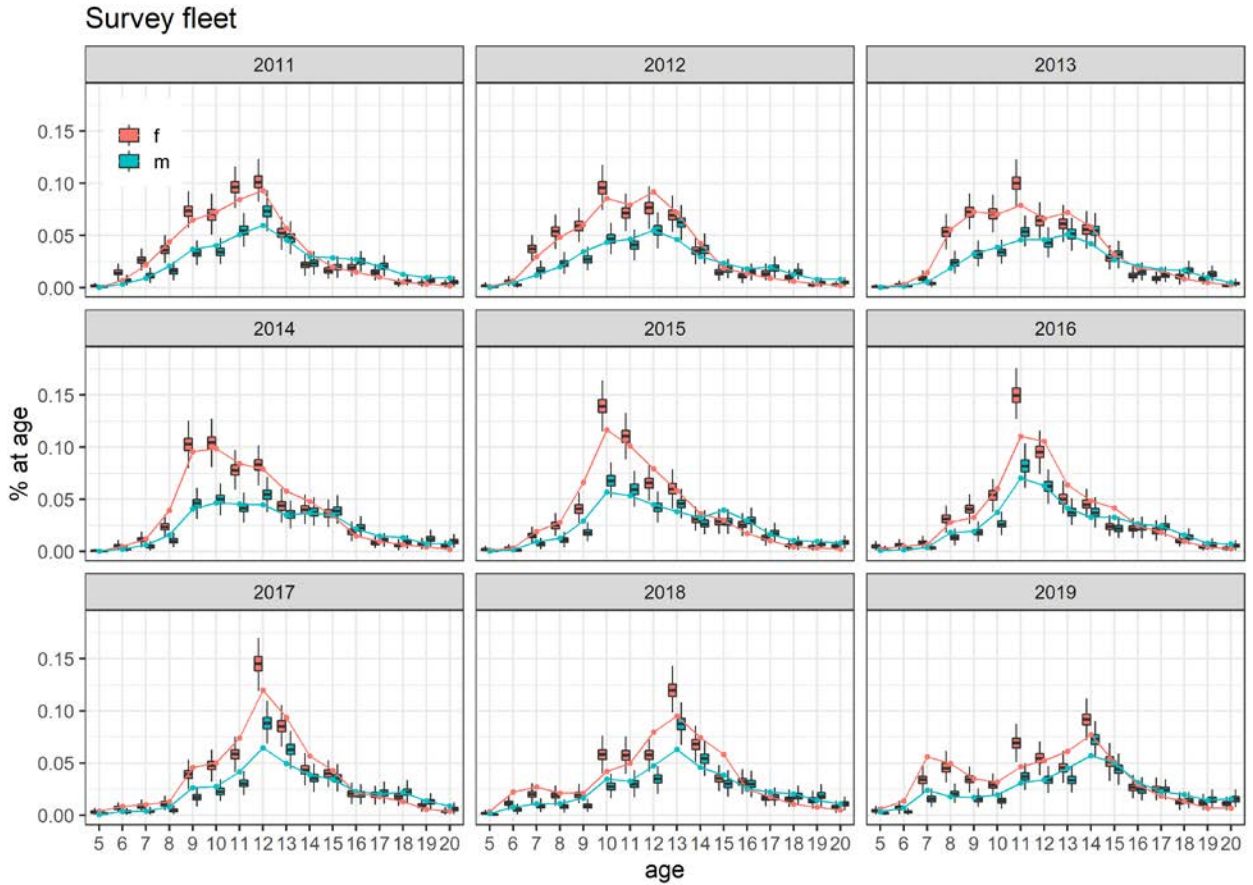
Data Generation

- MP code able to generate data similar to what is observed
  - NPUE
  - WPUE



Data Generation: proportions-at-age

Data generated *vs* observed age composition



Estimation model

- Average of two individual models used to represent the ensemble stock assessment:
  - Long and short coastwide models
  - Averaged to produce the TM and RSB estimates
  - Stock synthesis
- Streamlined to reduce simulation times:
  - Reduce the amount of data and length of the time-series
  - Mimic the recent observations/periods
  - Represent estimation uncertainty in projections

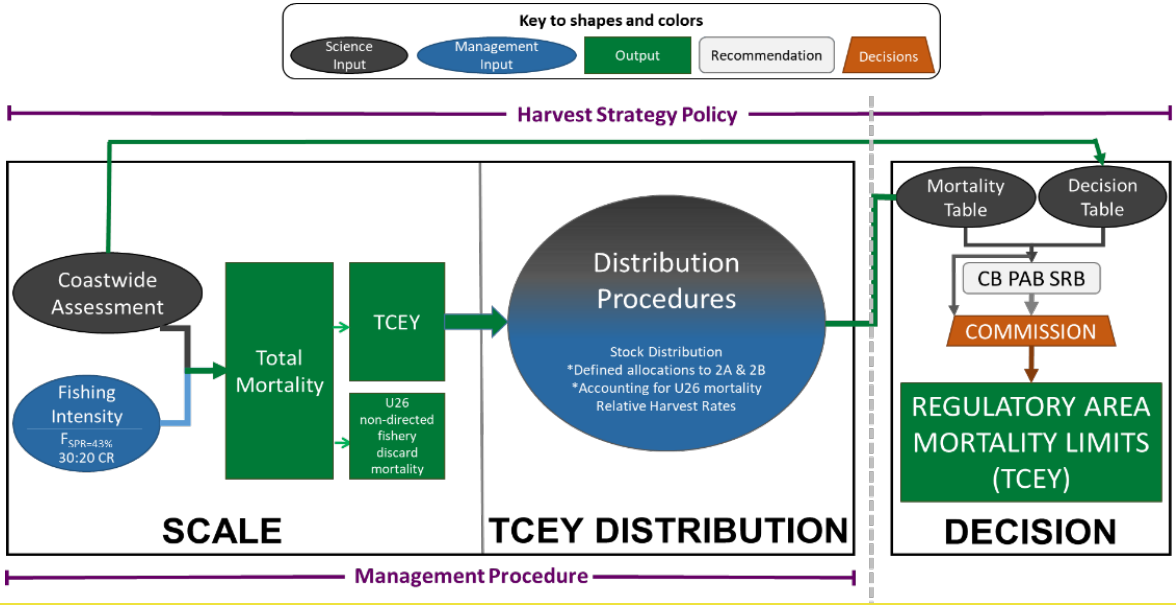
Estimation model performance

- 20 simulations → data generated using the approach described above
- Closed loop simulation (SPR 43% and 30:20 HCR)

- Performance of the estimation model:
  - RMSE relative to OM ~ 9%
  - Autocorrelation in the residuals = 0.974
  - Additional sources of variability will likely increase the estimation error

Procedure for distributing the TCEY

1. Coastwide target fishing intensity (SCALE)
2. Regional Stock Distribution (DISTRIBUTION)
3. Regulatory Area Allocation (DISTRIBUTION)
4. Annual Regulatory Area Adjustment (DECISION)



MSAB015

- ***IPHC-2020-MSAB015-R, para. 42****.The MSAB* ***AGREED*** *that the following elements of interest for defining constraints on changes in the TCEY, and distribution procedures be considered for the Program of Work in 2020:*
  - *constraints on the change in the TCEY can be applied annually or over multiple years at the coastwide or IPHC Regulatory Area level. Constraints on the change in TCEY currently considered include a maximum annual change in the TCEY of 15%, a slow-up fast down approach, multi-year mortality limits, and multi-year averages on abundance indices;*
  - *indices of abundance in Biological Regions or IPHC Regulatory Area (e.g. O32 or All sizes from modelled survey results);*
  - *a minimum TCEY for an IPHC Regulatory Area;*
  - *defined shares by Biological Region, Management Zone, or IPHC Regulatory Area;*
  - *maximum coastwide fishing intensity (e.g. SPR equal to 36% or 40%) not to be exceeded when distributing the TCEY;*
  - *relative harvest rates between Biological Regions or IPHC Regulatory Areas.*

MPs for evaluation in 2020

MP	Coastwide	Regional	IPHC Regulatory Area	Priority
MP 15-A	SPR 30:20		• O32 stock distribution • Proportional relative harvest rates (1.0 for 2-3A, 0.75 for 3B-4) • 1.65 Mlbs floor in 2A • Formula percentage for 2B	1
MP 15-B	SPR 30:20 MaxChange15 %		• O32 stock distribution • Proportional relative harvest rates (1.0 for 2-3A, 0.75 for 3B-4) • 1.65 Mlbs floor in 2A • Formula percentage for 2B	1
MP 15-C	SPR 30:20 MaxChange15 %	O32 stock distn Rel HRs: R2, R3=1, R4, R4B=0.75,	• O32 stock distribution • Relative harvest rates not applied • 1.65 Mlbs floor in 2A • Formula percentage for 2B	2
... K				

https://www.iphc.int/uploads/pdf/msab/msab015/iphc-2020-msab015-r.pdf

Multi-region operating model

- 4 Biological Regions
- 33 fisheries + 4 surveys
- Start year: 1888

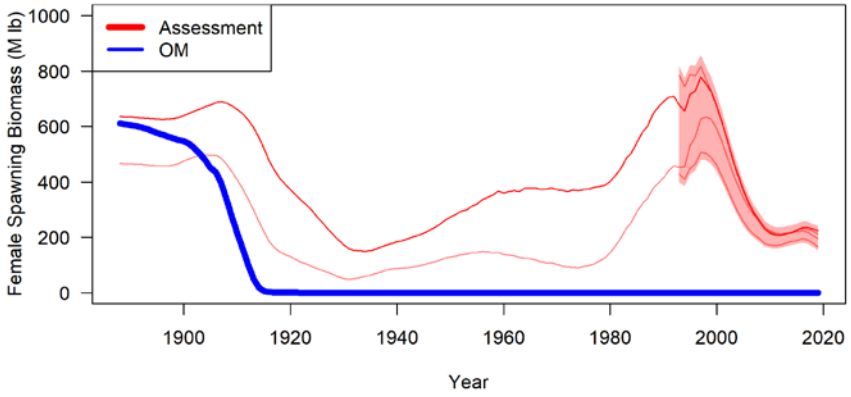
- Initial parameters from long AAF model
- Selectivity for surveys and directed commercial fishery made asymptotic

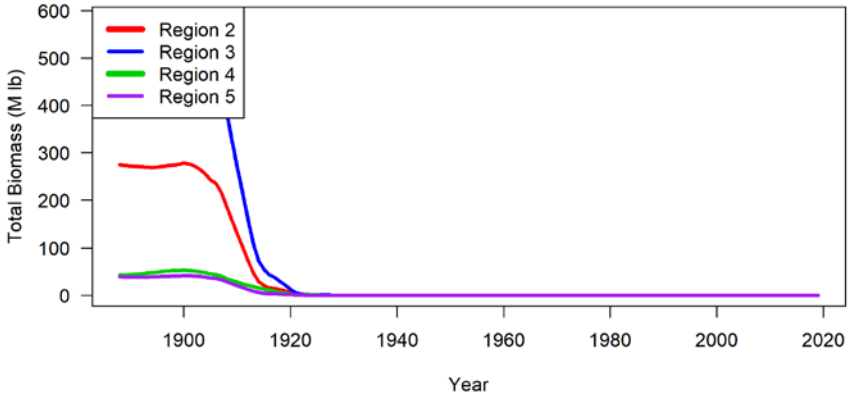
Conditioning the OM

- Goal was to develop a model representing the Pacific halibut population in the past and the future

- Comparisons when conditioning
  - Survey indices of abundance for each Biological Region
  - Stock distribution for each Biological Region
  - Predicted SB from long AAF stock assessment model
  - Predicted SB from ensemble
  - Survey proportions-at-age for each Biological Region

With movement from data



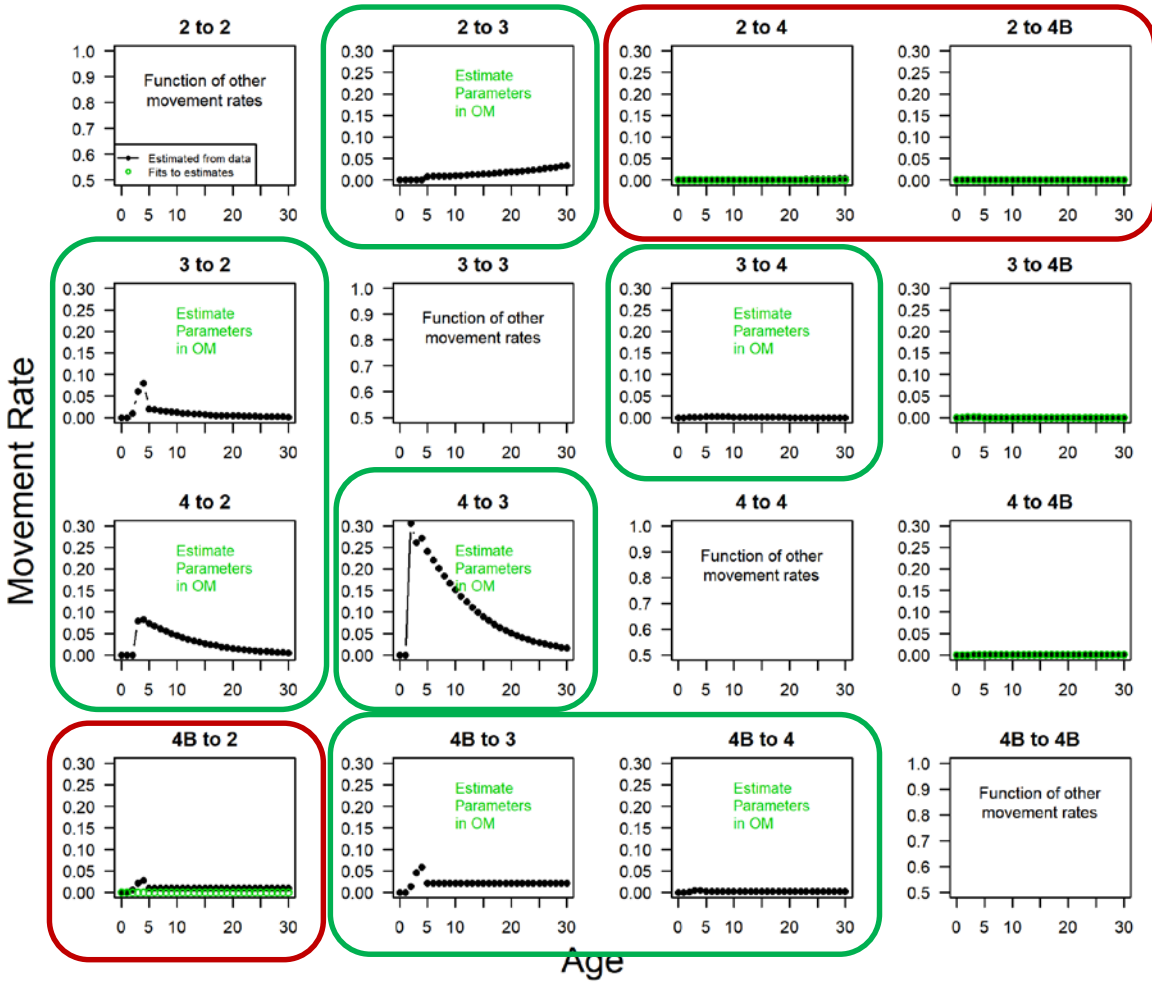


Fitting to predictions and data

- Estimated parameters:
  - R_0
  - Proportion of recruitment to each Biological Region
  - Movement
    - 2 to 3 (double exponential)
    - 3 to 2 (double exponential)
    - 3 to 4 (double exponential)
    - 4 to 3 (double exponential)
    - 4 to 2 (double exponential)
    - 4B to 4 (one value, age 5 and greater)
    - 4B to 3 (ages 3, 4, and 5+)

Movement in the OM

- Assumed no movement between Region 2 and 4B, and from 2 to 4
- Estimate movement in the OM



Fitting to predictions and data

- Objective functions
  - Lognormal likelihoods for SB and region-specific modelled survey indices
  - “Robustified” multivariate normal likelihoods for proportion of survey in each region and observed proportions at age from FISS data

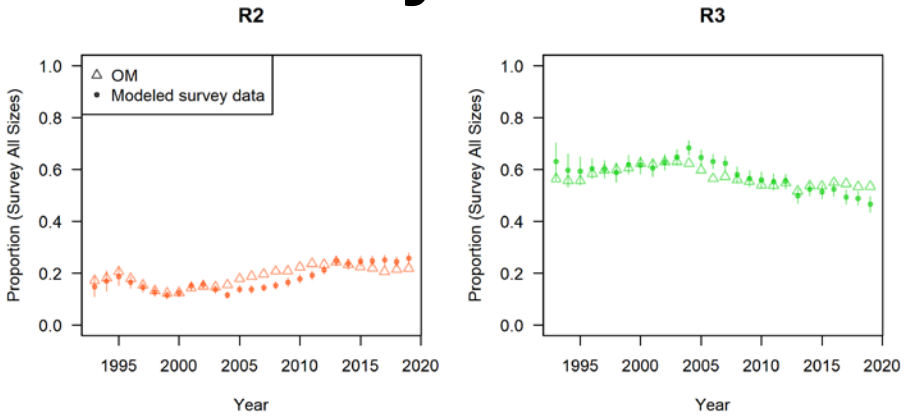
Fitting to individual data sources (likelihood)

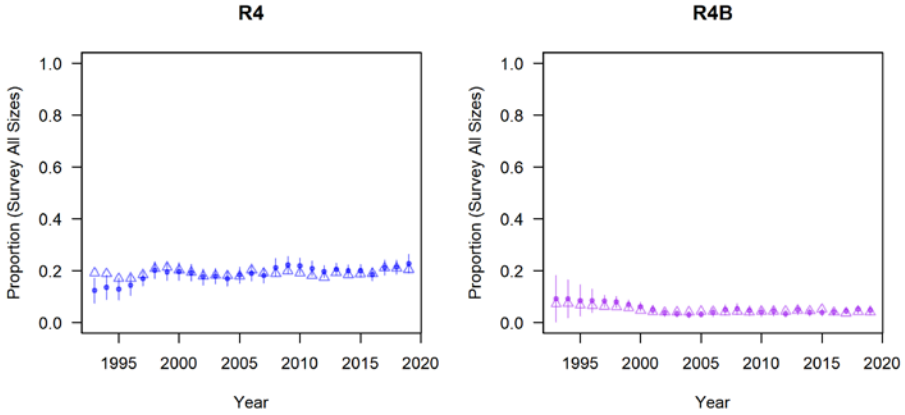
Model	Ensemble SB	Long AAF SB	Indices	Stock Distribution	Proportions-at-age
Ensemble SB only	**9**	549	15965	452	-2810
Distribution only	655	4963	1580	**141**	-5236
Distn Ens	**298**	9320	3056	**183**	-4869
Distn Index Ens 0.25	**678**	3056	**815**	**167**	-5239
Distn Index Ens 0.50	**206**	1371	**506**	**347**	-5149
Distn Index Ens 1.0	**168**	1318	**478**	**336**	-5192

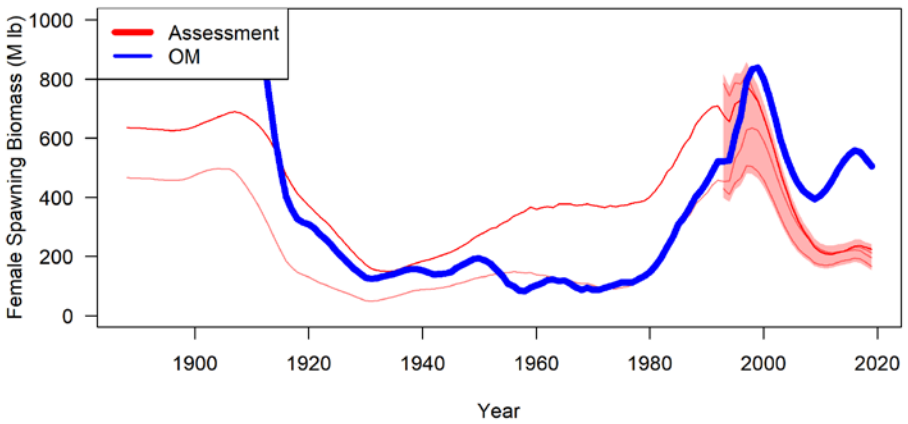
Tensions

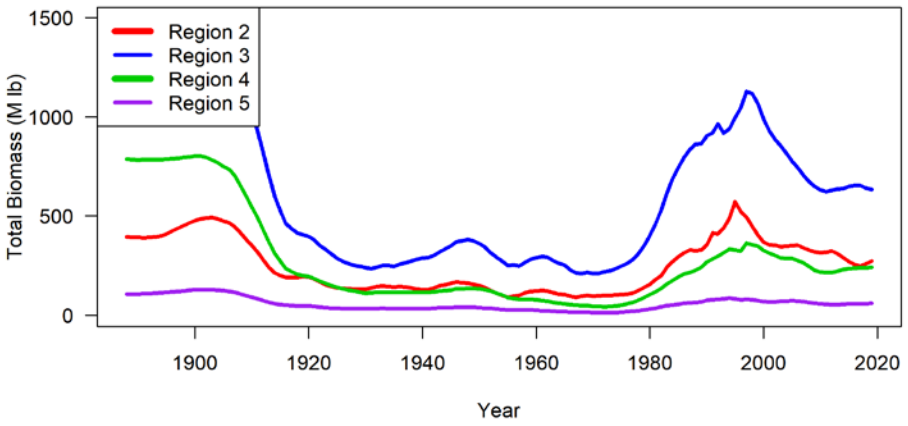
- Difficult to simultaneously fit to all data sources
- Fitting to only distribution
  - A large spawning biomass
  - Most of total biomass in Region 3
  - Poor fit to indices but captured patterns
- Fitting to only ensemble spawning biomass
  - Nice fit to entire spawning biomass time-series
  - Most of total biomass in Region 2
  - Very poor fit to distribution
  - Decent fit to indices in 2 and 3, very poor in 4 and 4B

Fit to only distribution

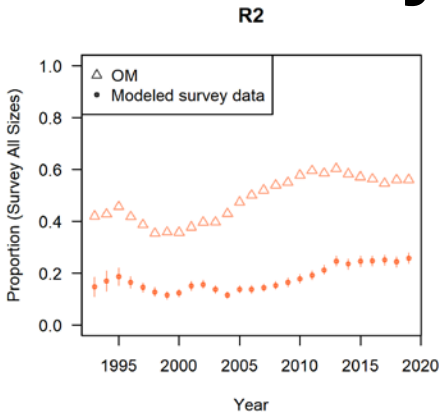


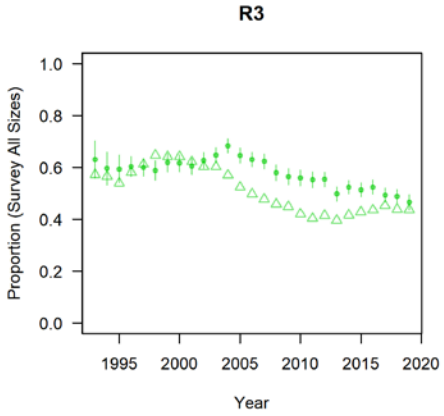


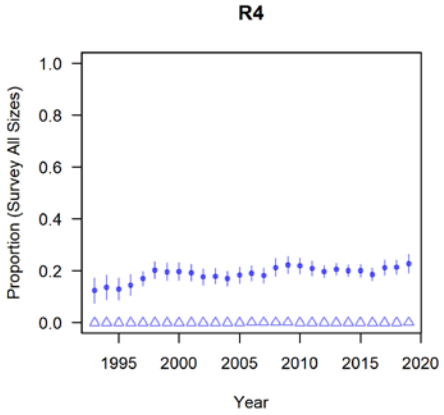


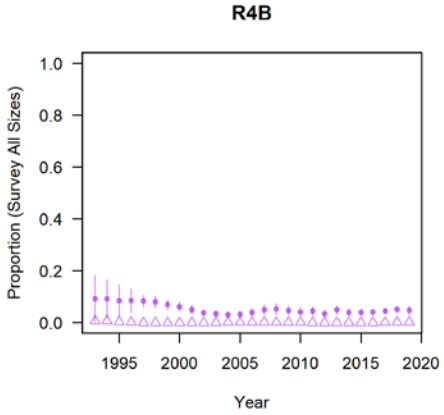


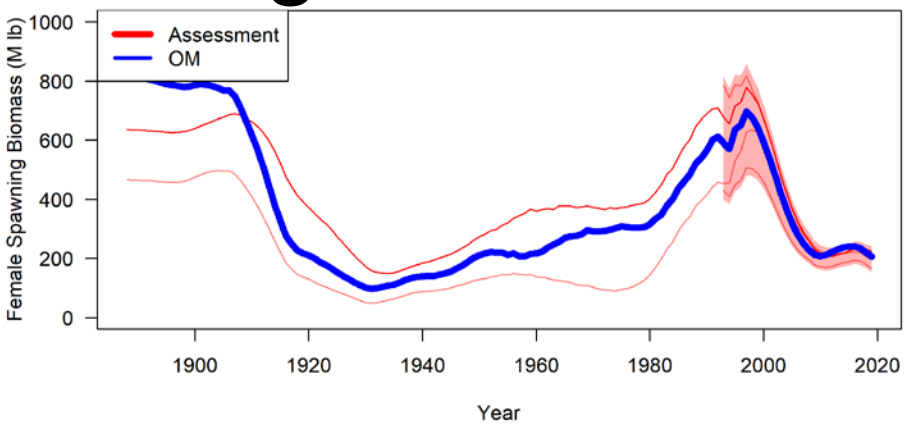
Fit to only ensemble spawning biomass

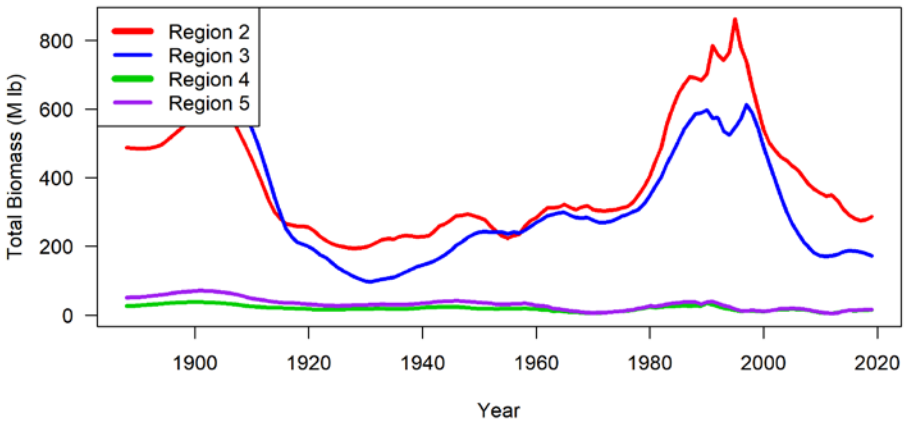






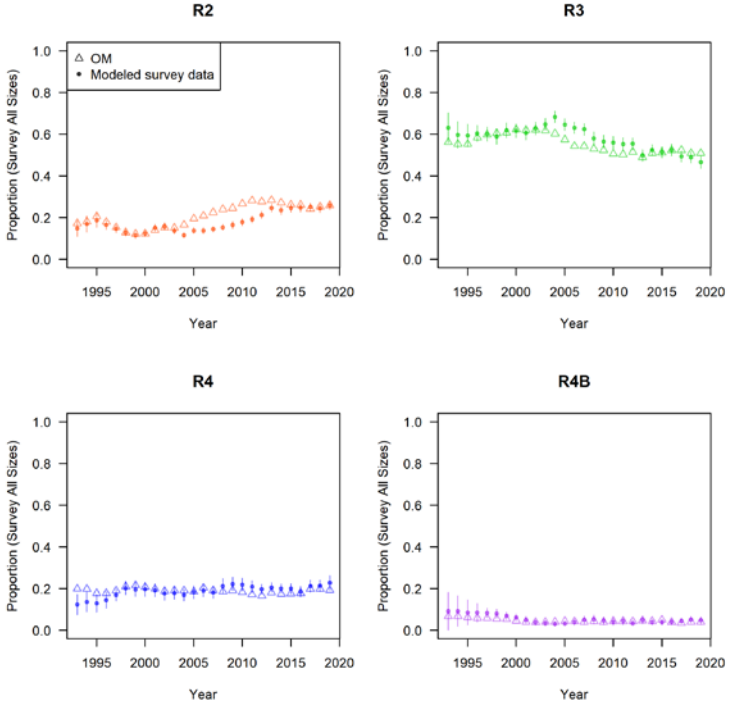




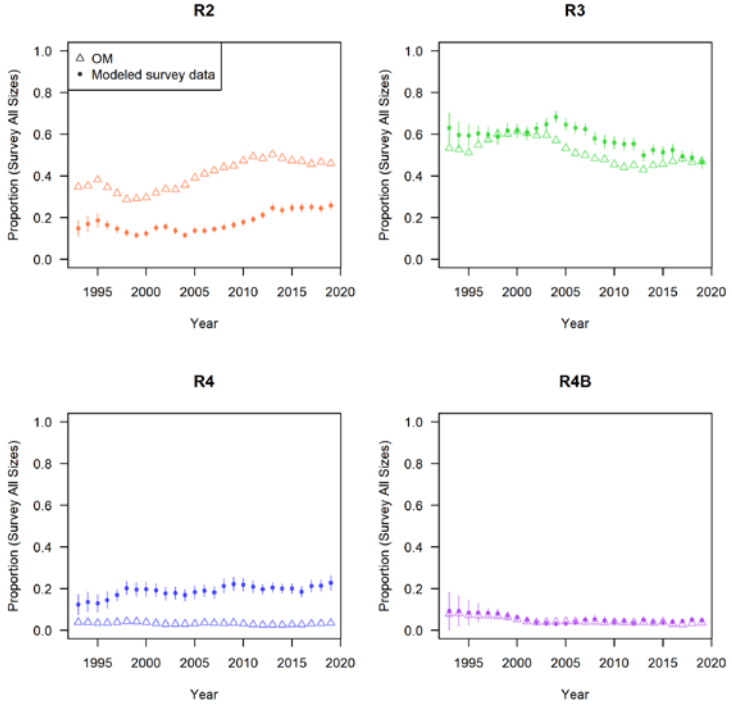


Balancing fits to distribution, index, ensemble

Weight
Index & Ensemble
0.25

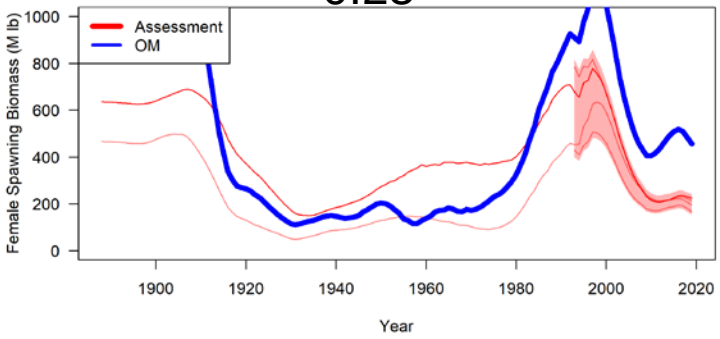


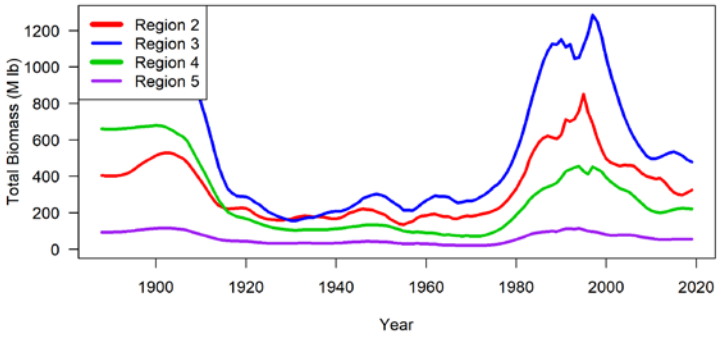
Weight
Index & Ensemble
0.50



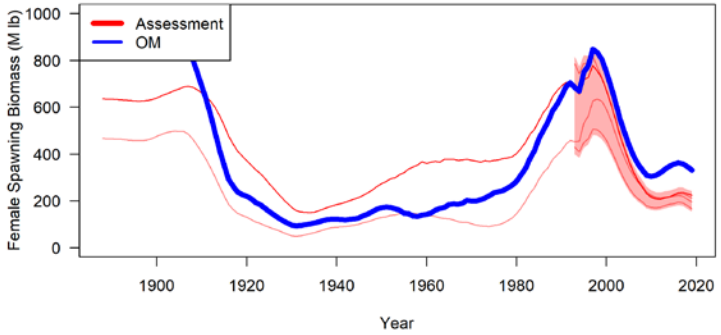
Balancing fits to distribution, index, ensemble

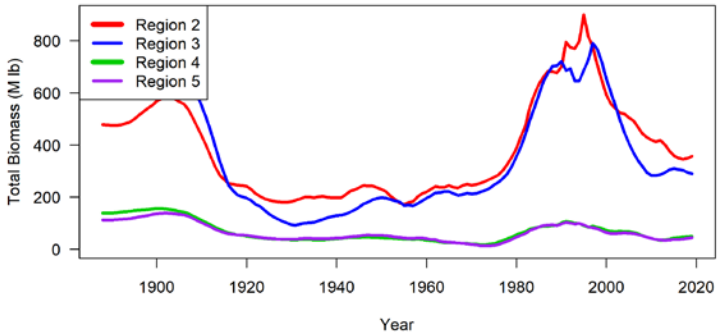
Weight
Index & Ensemble
0.25





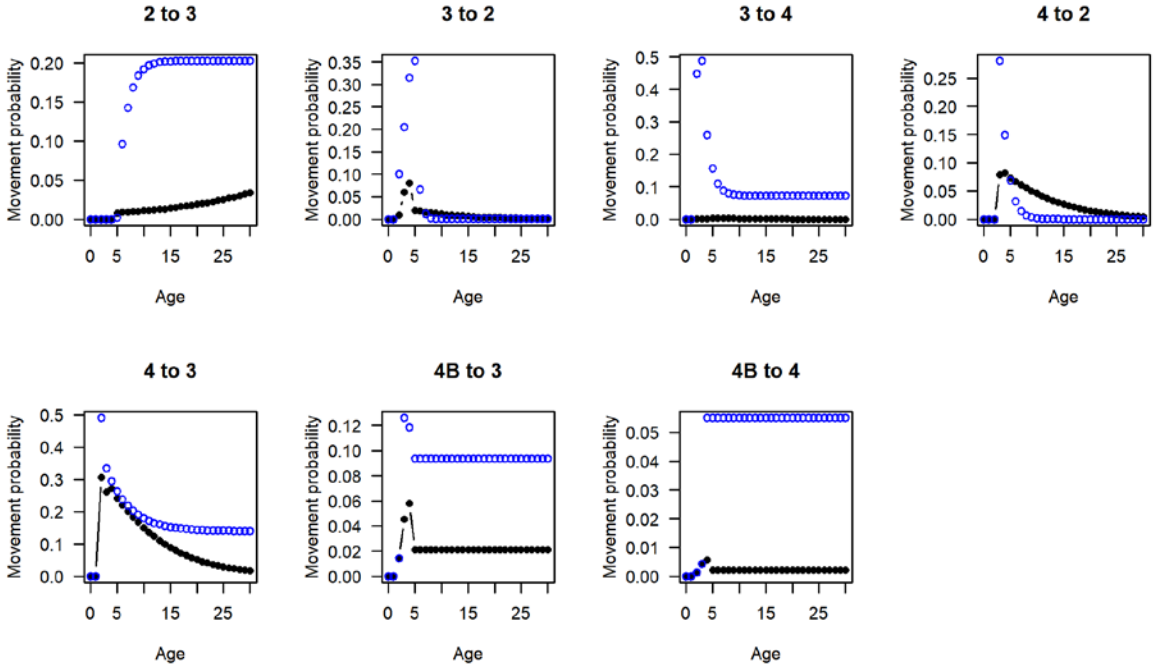
Weight
Index & Ensemble
0.50





Movement

- Estimated different than data suggest
  - Most data are from the last few decades
- Likely time-varying



Balancing index, distribution, and ensemble
(index and ensemble weighted 0.25)

OM conditioning solutions

- Likely time-varying movement
  - Certain periods (linked to PDO like recruitment)?
  - Density-dependent possibly?
- Likely time-varying distribution of recruitment
  - Linked to PDO like recruitment?
- Other parameters are fixed at AAF long estimates
- The optimization algorithm is not ideal

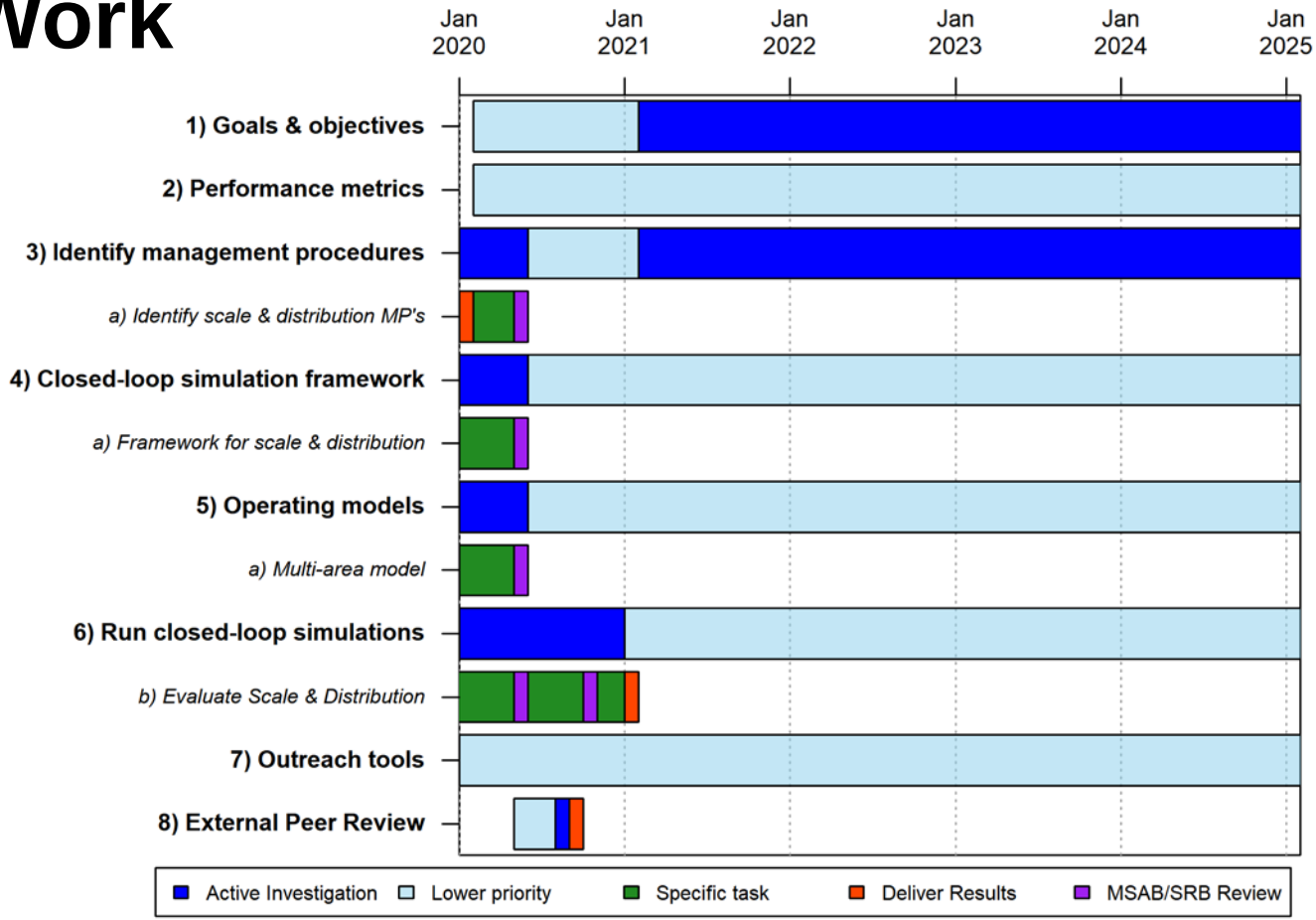
OM for simulations

- Many dynamics have been changing over the entire time-series
  - e.g., weight-at-age, selectivity
- It will be important to capture variability in the dynamics to determine MPs robust to many hypotheses

- Should conditioning be focused on matching data and/or simulating variability appropriately?

Program of Work

- Eight tasks



Program of Work

May 2020 MSAB Meeting (MSAB015)	Progress
Review Goals and Objectives (Distribution & Scale)	Completed
Review simulation framework	Completed
Review multi-area model	Completed
Review preliminary results	
Identify MPs (Distribution & Scale)	Completed
June 2020 SRB Meeting (SRB016)	
Review simulation framework	
Review multi-area model	
Review preliminary results	
August 2020 MSAB Special Session	
Evaluate preliminary results	
September 2020 SRB Meeting (SRB017)	
Review penultimate results	
October 2020 MSAB Meeting (MSAB016)	
Review final results	
Provide recommendations on MPs for scale and distribution	
Annual Meeting 2021	
Presentation of first complete MSE product to the Commission Recommendations on Scale and Distribution MP	

Recommendations

a) **NOTE** paper IPHC-2020-SRB016-08 Rev_1 which provides an update on the development of the IPHC MSE framework, a description of the specifications of the multi-area operating model, results from conditioning the multi-area operating model, and an overview of the implementation of management procedures.

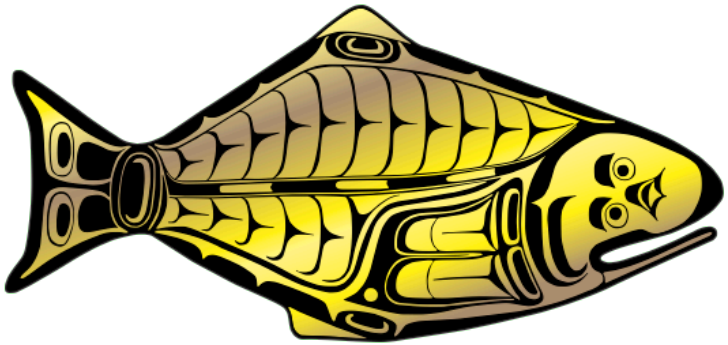
b) **RECOMMEND** alternative specifications and additional features of the OM or general description of management procedures needed to evaluate management procedures related to coastwide scale and distribution of the TCEY in 2020.

Recommendations

c) **RECOMMEND** additional parameterizations and structural components to implement in the multi-area OM for use as an operating model in the MSE simulations for 2020. Exploring the following may be useful

- Balancing the tensions by weighting data sets during optimization
- Implement time-varying movement, possibly linked to environment or density
- Implement time-varying proportion recruited to each region, possibly linked to environment
- Use a shorter time-series to condition the model, starting with a population that is not at unfished equilibrium
- Use parameters from other models within the ensemble (e.g., M and selectivity)

INTERNATIONAL PACIFIC



HALIBUT COMMISSION