L. Boiter

Defining the simulations to evaluate Fishing Intensity

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Purpose

- Discuss the framework of the closed-loop simulations
- Define the inputs for the closed-loop simulations to investigate *Scale* of the harvest policy
    1. The Operating Model (OM) and Scenarios
    2. Generation of data for the Estimation Model (EM)
    3. The EM's to use
    4. The details of the Harvest Strategy to simulate
    5. Management Procedures to simulate and evaluate
        - Fishing Intensity (FI) metric
        - Values for the FI metric
        - Control Rule
- Discuss some potential ways to present results

Review of AM093

- Harvest Policy outdated and a need to remove the blue line reference

- Provide a framework that allows strategic science-based approach to setting catch levels

INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC–2017–AM093–R Rev 1

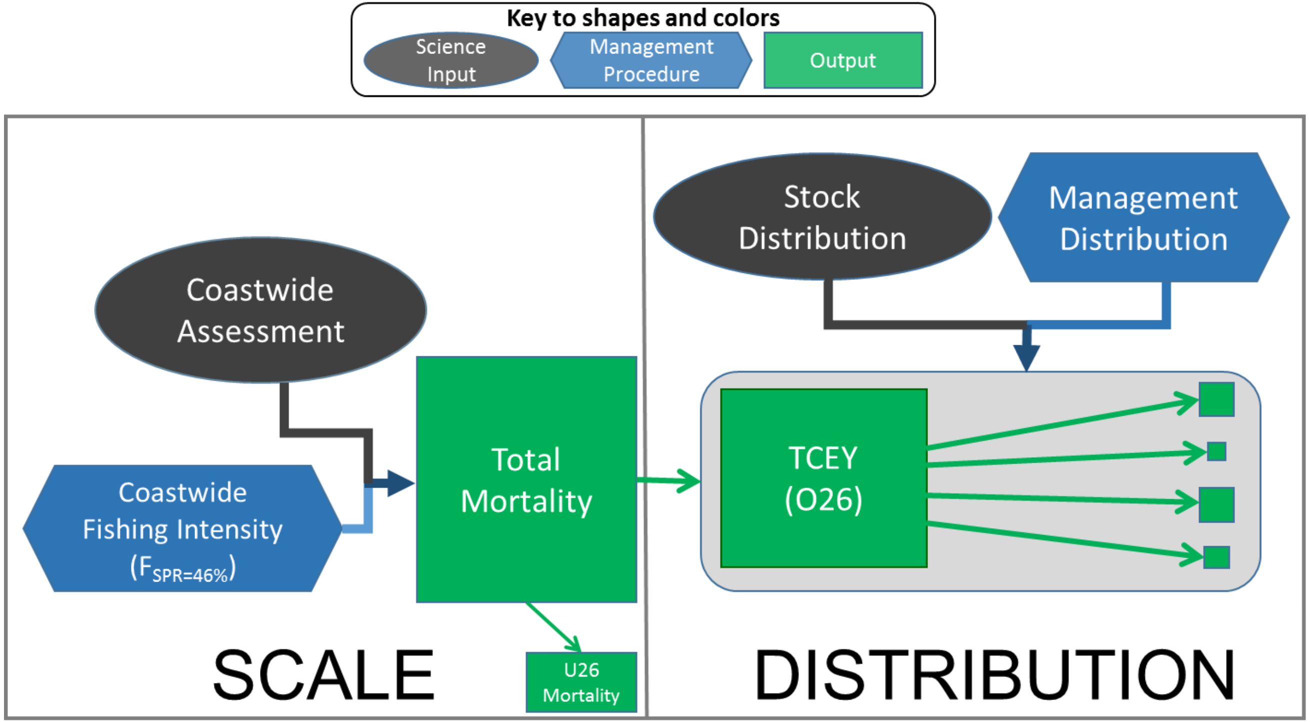
Report of the 93rd Session of the IPHC Annual Meeting (AM093)

Victoria, British Columbia, Canada, 23-27 January 2017

Review of AM093

- Noted a SPR-based harvest policy

- Separate Scale and Distribution
- Account for mortality of all sizes from all sources



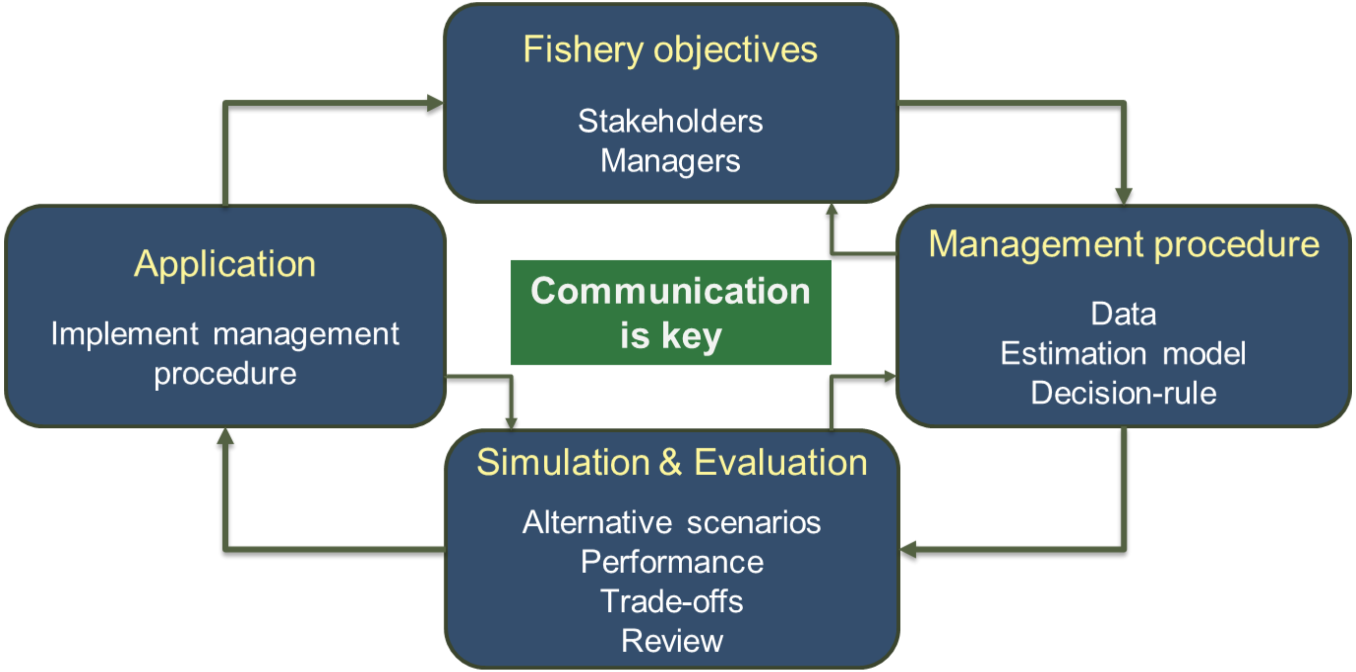
Review of AM093

- Status-quo SPR is an interim "hand rail"
- SPR=46%
- Average SPR from last three years

2017 Alternative	Total removals (M lb)	Fishery CEY (M lb)	Fishing intensity	Stock Trend: Spawning biomass in 2018 is less than 2017	Stock Trend: Spawning biomass in 2018 is 5% less than 2017	Stock Trend: Spawning biomass in 2020 is less than 2017	Stock Trend: Spawning biomass in 2020 is 5% less than 2017	Stock Status: Spawning biomass in 2018 is less than 30%	Stock Status: Spawning biomass in 2018 is less than 20%	Stock Status: Spawning biomass in 2020 is less than 30%	Stock Status: Spawning biomass in 2020 is less than 20%	Fishery Trend: Fishery CEY from the harvest policy in 2018 is less than 2017	Fishery Trend: Fishery CEY from the harvest policy in 2018 is 10% less than 2017	Fishery Trend: Fishery CEY from the harvest policy in 2020 is less than 2017	Fishery Trend: Fishery CEY from the harvest policy in 2020 is 10% less than 2017	Fishery Status: Harvest rate in 2017 is above target
No removals	0.0	0.0	$F_{100\%}$	<1	<1	<1	<1	3	<1	1	<1	<1	<1	<1	<1	0
FCEY = 0	11.2	0.0	$F_{77\%}$ 61%-84%	1	<1	3	<1	3	<1	1	<1	<1	<1	<1	<1	<1
	20.0	8.6	$F_{66\%}$ 49%-75%	5	<1	20	4	4	<1	3	<1	<1	<1	<1	<1	<1
	30.0	18.4	$F_{55\%}$ 39%-67%	32	<1	53	31	5	<1	6	<1	6	3	8	4	8
Blue Line	37.9	26.1	$F_{48\%}$ 33%-62%	58	8	77	55	6	<1	12	<1	47	33	48	39	50
status quo SPR	41.6	29.7	$F_{46\%}$ 32%-60%	68	6	87	64	6	<1	15	<1	57	45	57	49	61
Adopted	43.3	31.4	$F_{45\%}$ 30%-59%	71	10	90	67	6	<1	17	<1	70	57	69	58	74
	50.0	37.9	$F_{40\%}$ 27%-55%	92	29	98	88	7	<1	25	1	94	83	95	86	95
	60.0	47.7	$F_{35\%}$ 23%-51%	>99	52	>99	99	9	<1	37	3	>99	>99	>99	>99	>99

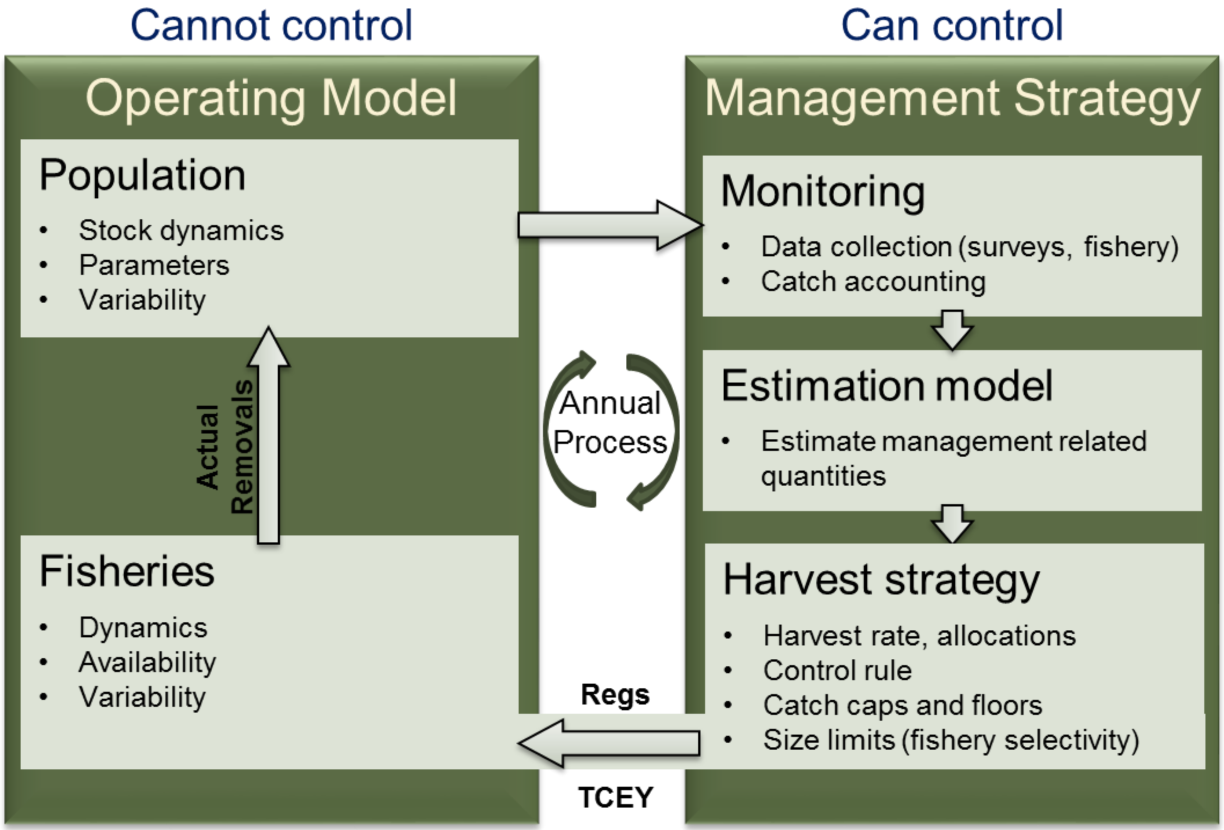
Review of AM093

- Use MSE to evaluate options for a modified harvest policy that separates Scale and Distribution, and accounts for all mortality
- Evaluate SPR values that are robust to possible bycatch scenarios



Simulation Framework

- Operating Model (OM)
- Monitoring (Data Generation)
- Estimation Model (EM)
- Harvest Strategy



Operating Model (OM)

- A representation of the population and the fishery
- Produces the numbers-at-age, accounting for mortality and any other important processes
- Incorporates uncertainty in processes
- Complexity driven by
  - The questions being asked
  - The knowledge to parameterize
  - The time available to develop and run

OM modeling platforms

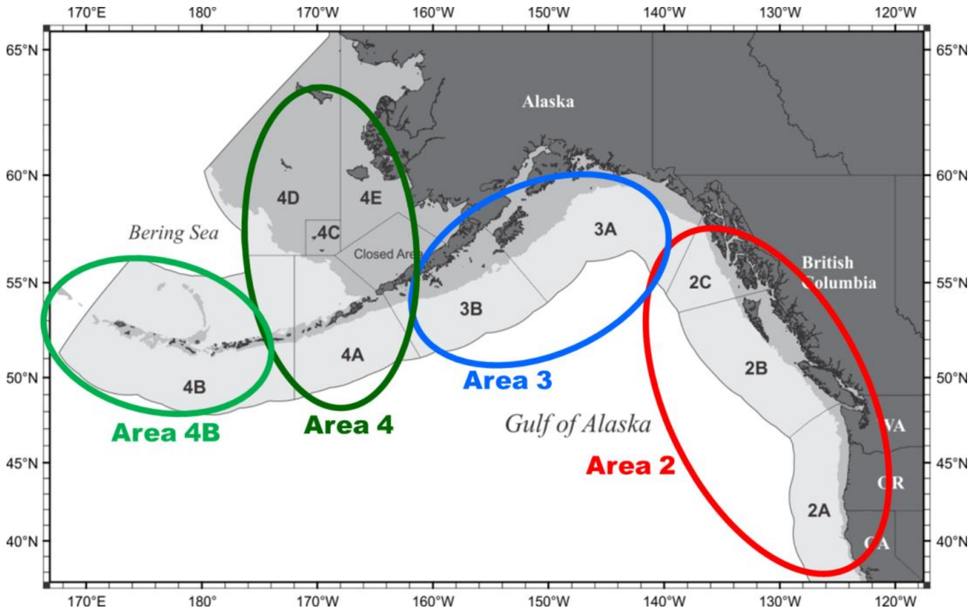
- Use Stock Synthesis and current assessment setup
  - Currently conditioned to data
- Using my own model will require additional time
  - Coding
  - Testing
  - Conditioning

OM specifications

- Coastwide or Fleets-as-areas
- Five fleets plus a survey in coastwide model
    1. Commercial
    2. Wastage
    3. Bycatch
    4. Sport
    5. Personal
    6. Survey

Should we use fleets-as-areas?

- Need to distribute directed fishery catch to areas
- Does not treat non-commercial catch as fleets
- Need to also distribute survey observations
- Slower run times
- Use all 4 assessment models as OM



OM uncertainty

- Uncertainty is estimated when fitting to data
- Uncertainty can be assigned to fixed parameters
- Multiple models provide structural uncertainty

Monitoring (Data Generation)

- Code to simulate observations from the OM that is used by the Estimation Model (EM)
- Data to generate are determined by the EM used and the structure of the harvest strategy

Estimation Model (EM)

- Mimics the model and processes used to estimate quantities needed for the harvest strategy
  - IPHC uses an ensemble of four assessment models
  - Produces a decision table with one row representing the current harvest policy
- The EM provides additional uncertainty to the variability in the OM
  - Can also be set up for misspecification

EM methods

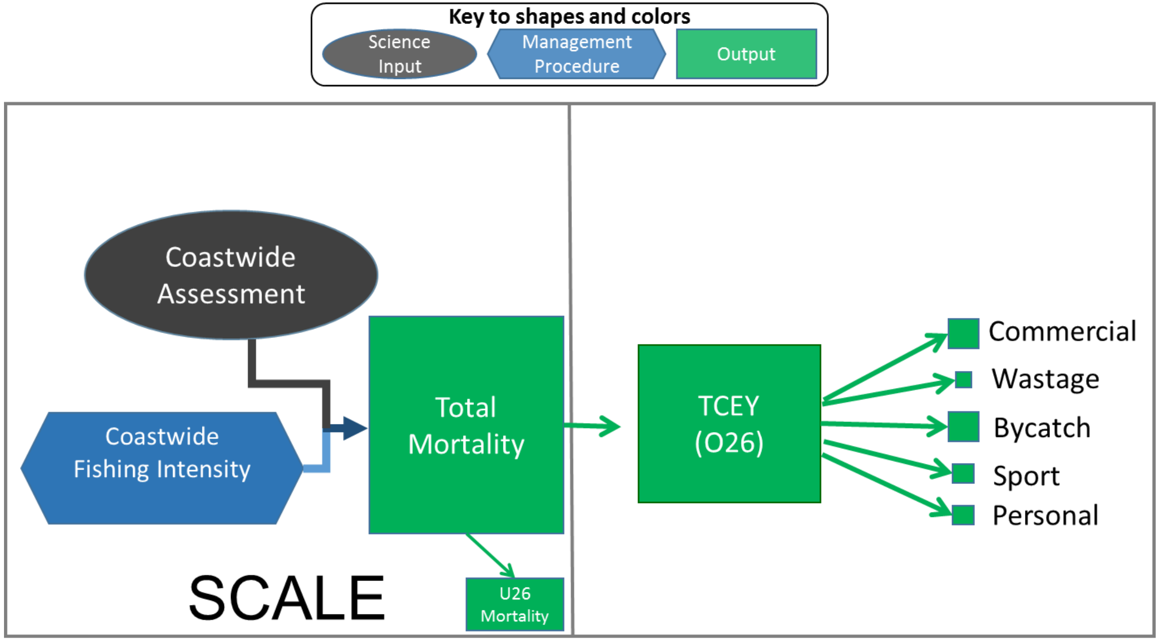
- Perfect Information
  - Quantities needed for harvest strategy are know exactly
- Simulate Error
  - Take the abundance from the OM and apply error to it
- Single stock assessment
  - An assessment model using generated data
- Ensemble of models
  - Multiple assessment models combined

Harvest Strategy

- A coastwide Fishing Intensity
- A control rule (i.e., 30:20)
- Catch sharing plans to allocate catch to sectors

Harvest Strategy

- Do not need to distribute the TCEY to evaluate Fishing Intensity
  - Use coastwide models
  - Make assumptions about allocation to five fleets



Can we distribute TCEY?

- With a coastwide model, we can pseudo-distribute the TCEY to Regulatory Areas
- Partition TCEY into sectors based on Area
- Evaluate different Fishing Intensities among areas

Can we distribute TCEY?

$$TCEY_A = TCEY \frac{\rho_A \times F_A}{\sum_A \rho_A \times F_A}$$

- The symbol ρ_A, formerly know as apportionment
  - The proportion of the O32 stock in each Regulatory Area
- F_A is the relative fishing intensity in each Area
  - If fishing intensity is the same for all Areas, then F_A=1

Psuedo-previous harvest policy

- F_A can be based on 16.125% and 21.5%, or anything else
  - The problem is that there is not feedback from the population
- ρ_A is difficult without a multi-area model
  - Could possibly sample proportions from past realizations
  - Could indicate how TCEY is distributed and inform sector specific catches
  - Would introduce additional variability

Coastwide or pseudo-areas?

Coastwide		Pseudo-Area	
Pros	**Cons**	**Pros**	**Cons**
Simple	Won’t provide for Fleets-As-Areas OM	Provide for Fleets-As-Areas OM	More complicated. (how is TCEY distributed)
Focused on coastwide FI	No relative difference between Areas	Can investigate relative FI in Areas	No feedback from population in those Areas
	Assumptions to split TCEY to sectors	Split TCEY into sectors for each Area	Many assumptions when distributing TCEY and splitting in each Area
	Won’t provide insight into Area-specific objectives		Won’t provide insight into Area-specific objectives

Should we distribute TCEY?

- Not a lot of benefit without a multi-area model
  - No feedback from the population
  - Assumptions to distribute TCEY may add more variability than necessary (or may get it wrong)
  - We should deal with distribution appropriately using a multi-area operating model
- Benefits
  - More realistic uncertainty
  - Determine sector catches more realistically within areas

My suggestions for the framework

Operating Model (OM)

- Stock Synthesis: Coastwide Model or Fleets-As-Areas?
- Use multiple models (e.g., two coastwide)
- Five fleets, as in assessment models
  - TCEY assigned as defined in Scenarios
- Uncertainty incorporated via two methods (Scenarios)
  - Parameter uncertainty from the estimated assessments
  - Structural uncertainty
    - Two models and other parameters as defined by MSAB

My suggestions for the framework

Estimation Models (EM)

- Perfect Information
  - as a reference
- Ensemble of two coastwide models
  - If not too time-consuming
  - Otherwise
    - a single assessment with additional error added
    - simply simulate error

My suggestions for the framework

Harvest Strategy

- A coastwide Fishing Intensity
- A control rule (e.g., 30:20)
- Catch assigned to sectors based on past and future expectations (with variability)

My suggestions for the framework

Data Generation

Data	Sexes	Prob Distn	Bias?*	Uncertainty
Survey NPUE	Combined	Lognormal	*No*	From Assessment
Survey age comp	Separate	Dirichlet	Selectivity?	From Assessment
Survey U26 age comp	Separate	Dirichlet	Selectivity?	From Assessment
Fishery WPUE	Combined	Lognormal	*q?*	From Assessment
Fishery age comp	Combined	Dirichlet	Selectivity?	From Assessment
Bycatch age comp	Combined	Dirichlet	Selectivity?	From Assessment
Sport age comp	Combined	Dirichlet	Selectivity?	From Assessment

*Bias is whether there is a difference between generated data and EM

Scenarios

- Uncertainty we cannot or choose not to control
  - Not part of a management procedure
  - Goal is to develop a management strategy robust to these uncertainties

Scenarios (Decisions)

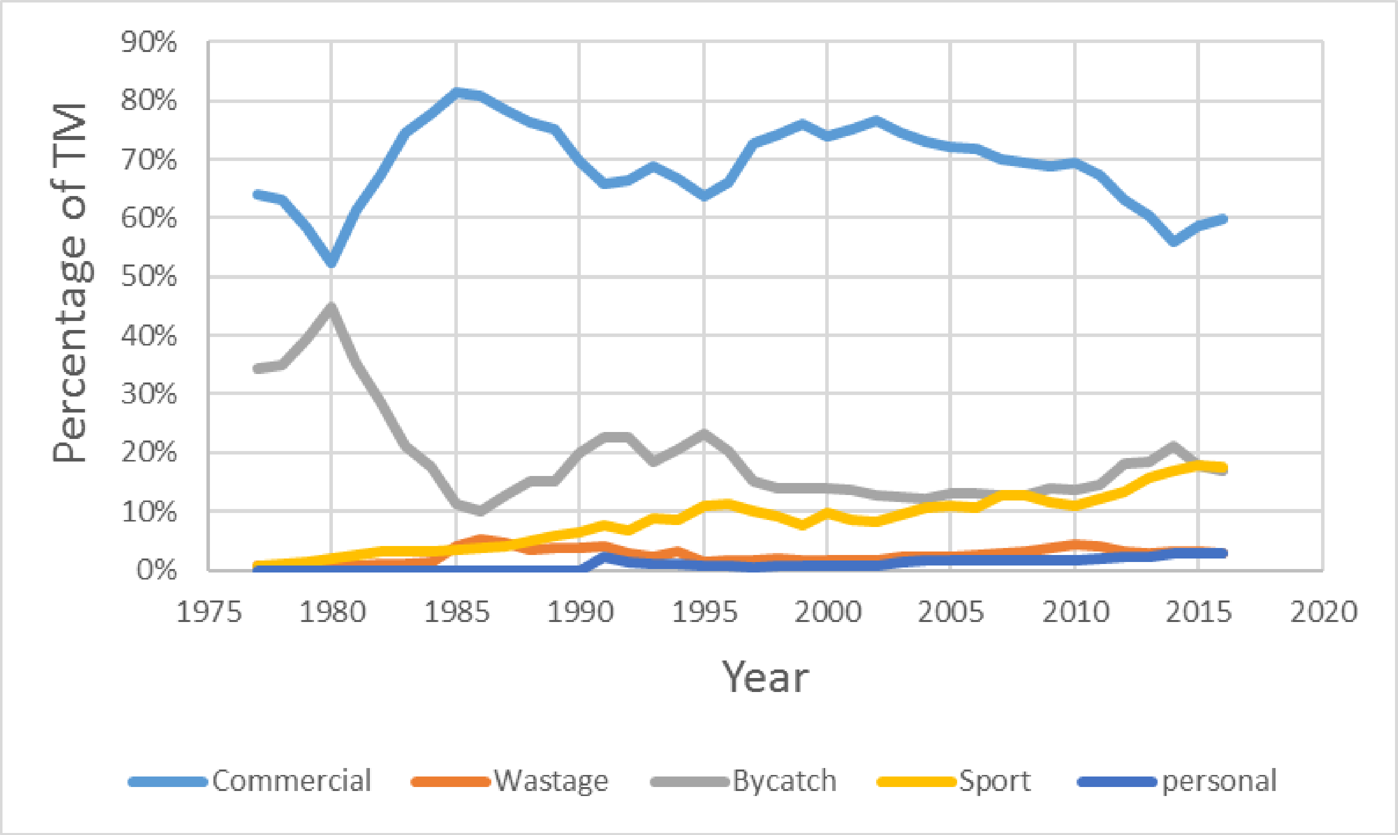
Process	Uncertainty
Natural Mortality (M)	From assessment
Recruitment	Random, lognormal deviations, variability=0.5-0.65
Size-at-age	Trend in size-at-age (random walk)
Maturity-at-age	Variable a50; function of size-at-age?
Steepness	Variability in OM: N(0.75, σ=0.1)
Regime Shifts	Autocorrelated index as indicator for regime shift
Fishery Selectivity	Time-varying, consistent with estimated variability
Survey Selectivity	Time-varying, consistent with estimated variability
WPUE catchability	Random walk as estimated
Survey catchability	Constant
TCEY to sectors (e.g., bycatch)	*See next slides*
Prop of TCEY taken	Based on historical distribution, all sectors

Allocate simulated TCEY to sectors

- First determine how the total mortality (TM, catch) relates to the TCEY
  - I can look at recent total utilization
  - Will need to make assumptions about U26 and O26
  - Is there a maximum catch or minimum catch?
- Then allocate TM to sectors
  - Using recent observations and future expectations
- Include variability

TM to sectors

- Once I have determined coastwide catch from the TCEY
- Allocate catch to sectors

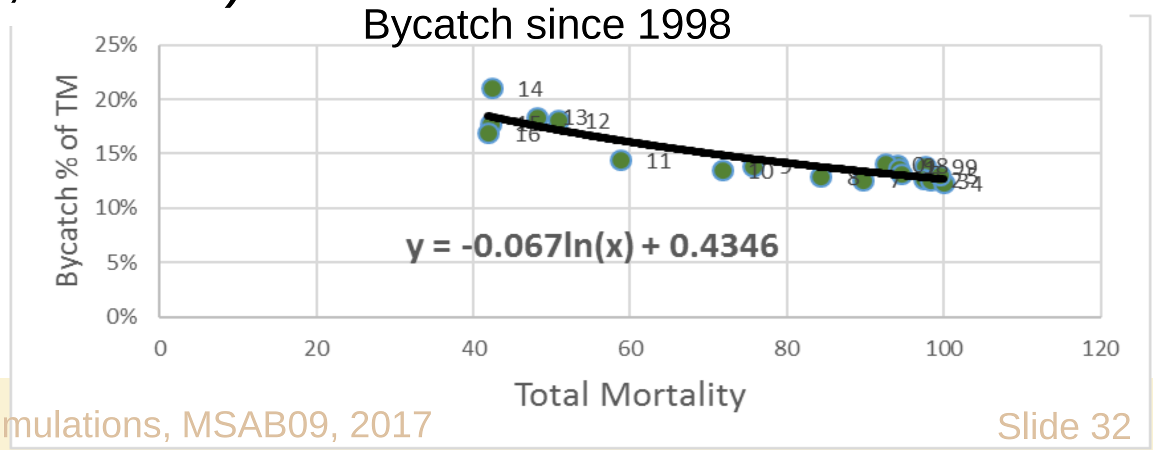


TM to sectors

- Define proportions of TM for each sector
  - Can depend on total TM
    - Sport, Personal, Bycatch a higher % when catch low
    - Wastage a function of Commercial
  - Can incorporate variability
    - Scenarios for bycatch, etc.
- For fleets-as-areas
  - First distribute to areas, then to sectors within areas

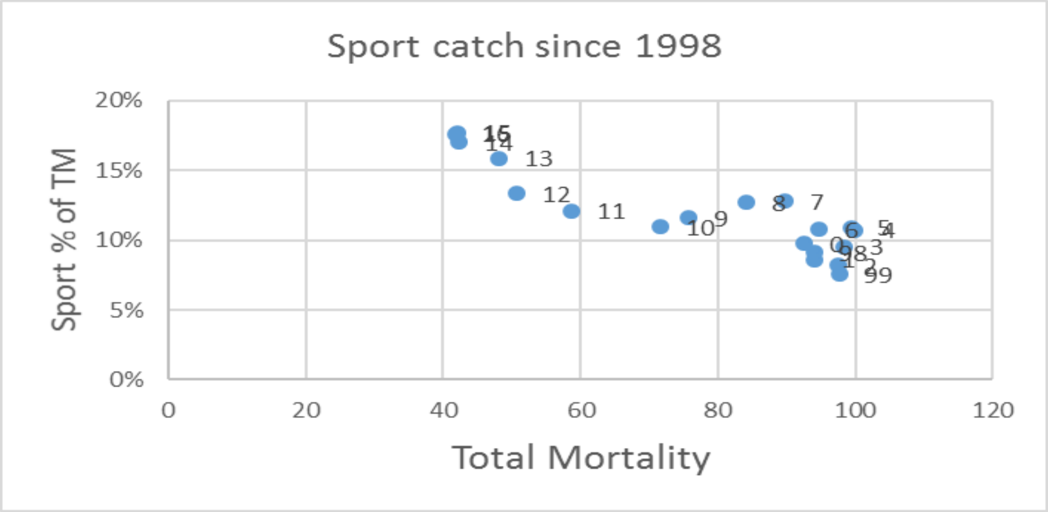
TM to sectors

- Determining TM for each sector
  - Personal ~ N(1.2 Mlbs, σ=0.2) then determined as %
  - Bycatch(%) = 0.4346 - 0.067ln(TM)
    - Intercept ~ N(0.4346, σ=???)
    - Slope ~ N(0.067, σ=???)



TM to sectors

- Determin
  - Persona ed as %
  - Bycatch
    - With
  - Sport
    - 11% when TM ≥ 60Mlbs
    - 33.02 - 0.367(TM) when TM < 60Mlbs
      - TM=60, Sport%=11%
      - TM=40, Sport%=18.3%

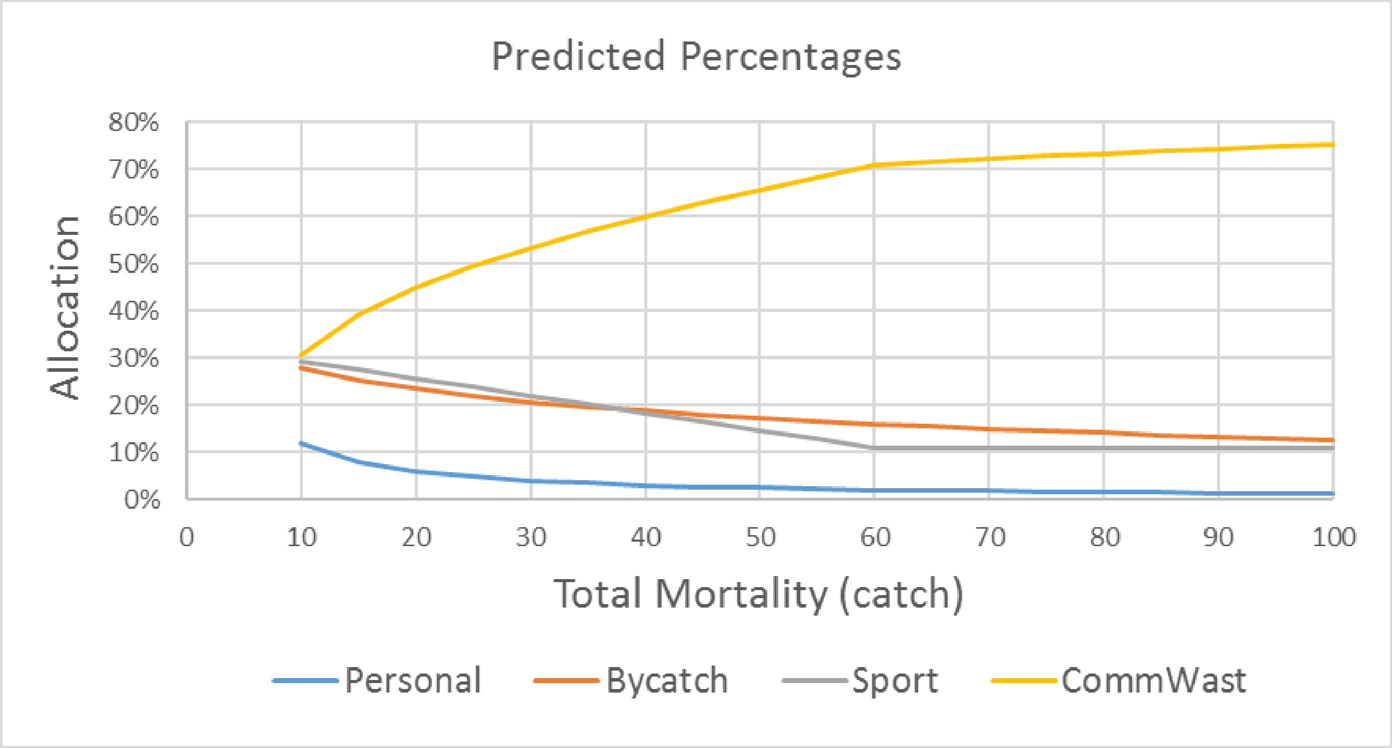


TM to sectors (Decisions)

- Determining TM for each sector
  - **Personal** ~ N(1.2 Mlbs, σ=0.2) then determined as %
  - **Bycatch**(%) = 0.4346 - 0.067ln(TCEY)
    - With variation
  - **Sport**(%) = 33.02 - 0.367(TCEY) with a minimum of 11%
    - With variation
  - **Commercial** + **Wastage** is remaining %
    - Wastage(%) is a function of O32 (age proxy)

TM to sectors (Decisions)

- Determining Total Mortality (catch) for each sector



Management Procedures

- We will consider two management procedures to evaluate concurrently
  - Fishing Intensity
  - Control Rule

Fishing Intensity metrics

What we want in a metric

- As fishing effort increases, the fishing intensity metric also increases appropriately
- Applies to simple as well as complex models
- Metric changes with changes in selectivity, and captures systematic changes in selectivity
- Easy to compute
- A scale that is easy to understand

Thanks to Owen Hamel for his insights

Exploitation Rate (U)

- Catch divided by a exploitable biomass
  - For a single fleet
- A summary biomass is used when multiple fleets have different selectivities
  - Ignores difference between fisheries and impacts on size, age, and sex
- Not a useful metric when more than one fleet
- Not consistent with changing selectivity

Instantaneous Fishing Mortality (F)

- Fishing mortality on most highly selected age, size, and sex
- Catch is a function of F and selectivity
  - A change in selectivity changes the meaning of F
- Scale not easily interpreted
- Is a useful parameter for modelling, but not so much for fishing intensity

Fishing Ratio

$$\frac{\text{Biomass of fish that die due to fishing}}{\text{Biomass of fish that die due to natural causes}}$$

- A useful metric to gauge current impacts due to fishing
- Could be used to set a maximum impact in a given year
- Does not directly relate to spawners

Spawning Exploitation Rate (SER)

- A measure of reduction in SB due to fishing
  - Called Annual Foregone Reproduction by Mace (1996)
- SRB suggestion to consider this metric

$$SER = 1 - \frac{SB_{fishing,y}}{SB_{noFishing,y}}$$

- Does not directly account for mortality of smaller fish
- May be sensitive to shifts in selectivity
- May be interesting to report annually

Relative Foregone Yield (RFY)

$$\frac{\text{Equilibrium yield with current conditions and FI}}{\text{Max equilibrium yield with current conditions}}$$

- Percentage of MSY (given current conditions)
- Related to “Pretty Good Yield” (Hilborn 2010)
- Not certain which side of the yield curve
- May be useful to report and monitor, or as a performance metric

Spawning Potential Ratio (SPR)

- A measure of the effect of fishing on the long-term reproductive potential of the stock
- If you were to fish a this exact rate, what percentage of the spawning potential would remain
- SPR=100% is no fishing
- SPR=40% is a 60% reduction
- Commonly used for management
  - Currently used in IPHC interim HP

$$SPR = \frac{\widetilde{SBPR}_F}{\widetilde{SBPR}_{noF}}$$

Equilibrium Relative Spawning Biomass (ERSB)

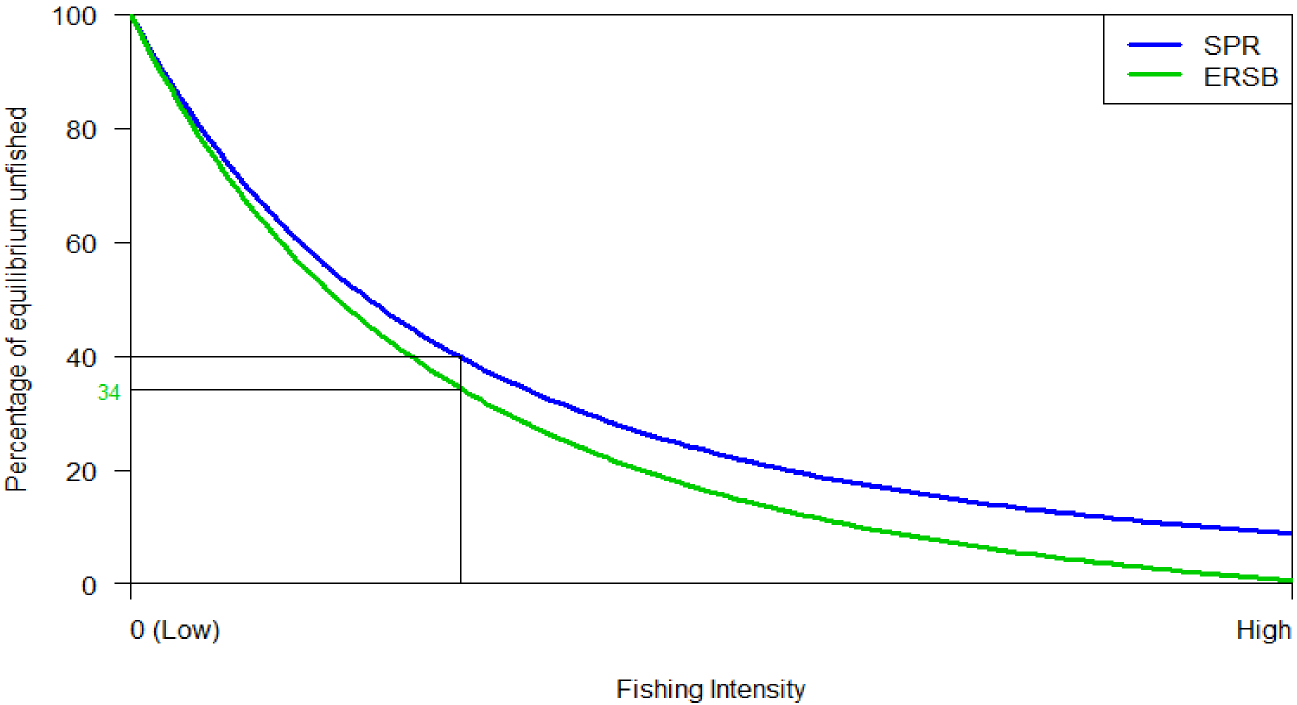
- Uses current conditions to calculate equilibrium spawning biomass
- Similar to SPR, except not per-recruit
- Can be calculated directly from SPR and steepness
- May be a better metric to use for the control rule

$$ERSB = \frac{\widetilde{SB}_F}{\widetilde{SB}_{noF}}$$

$$ERSB = \frac{4hSPR + h - 1}{5h - 1}$$

A comparison of SPR and ERSB

- Steepness = 0.75



A comparison of fishing metrics

Metric	Multiple fisheries and areas	Equili-brium	Easy to calc-ulate	Easy to inter-pret	Range	Account for fishing mortality on all sizes	Current conditons or regime	Use?
U	No	No	Yes	Yes	0–100%	No	Possibly	Leave to Modelling
F	No	No	Yes	No	0–∞	No	Yes	
SPR	Yes	Yes	Yes	Yes	0–100%	Yes	Yes	For FI
ERSB	Yes	Yes	Yes	Yes	0– >100%	Yes	Yes	For CR
FR	Yes	No	Yes	Yes	0–∞	Yes	Yes	Report or performance metric
SER	Yes	No	Yes	Yes	0–100%	Yes	Yes	
RFY	Yes	Yes	Yes	Yes	0–100%	Yes	Yes	

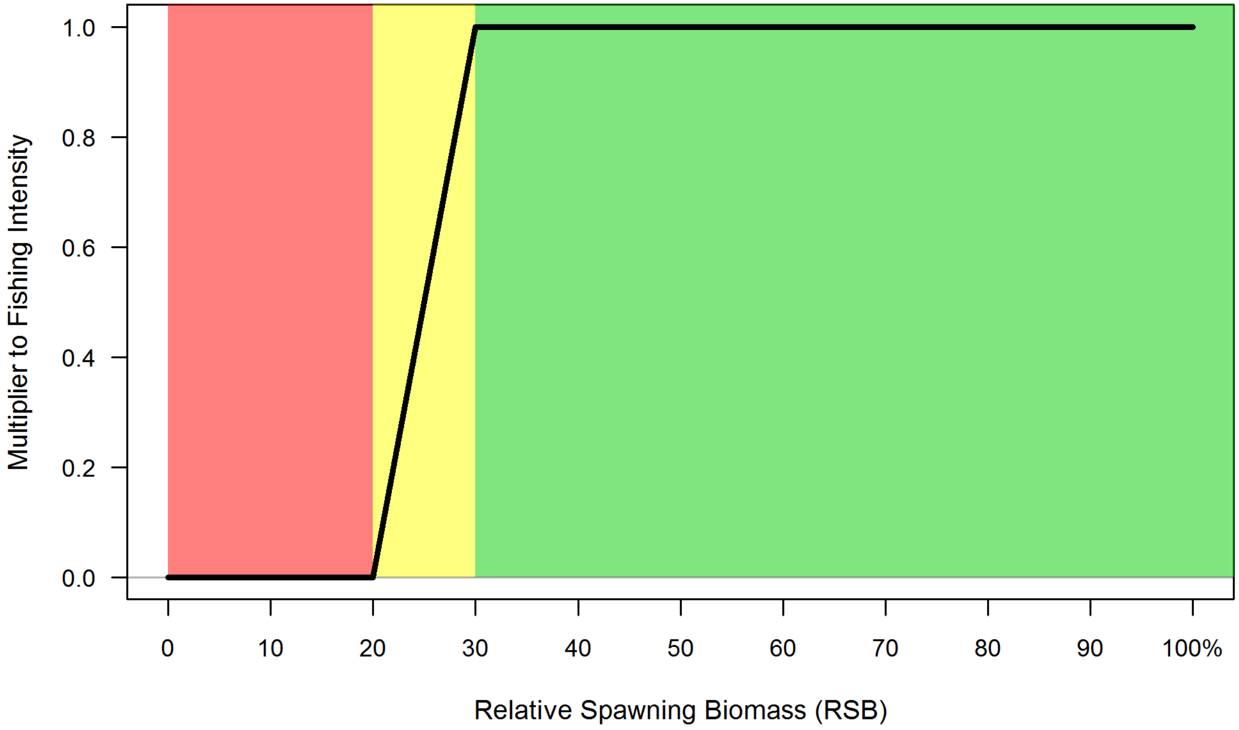
Management Procedures for FI (Decisions)

- **Which metric(s) to use to set scale?**
  - I suggest F_{SPR}
  - Possibly report FR, SER, and RFY as performance metrics

- **Which values for the metric(s)**
  - I suggest SPR = 0.25 to 0.60 by 0.05
    - Also SPR = 0.46 for status quo
    - Additional values that I feel would fill in the results

Control Rule

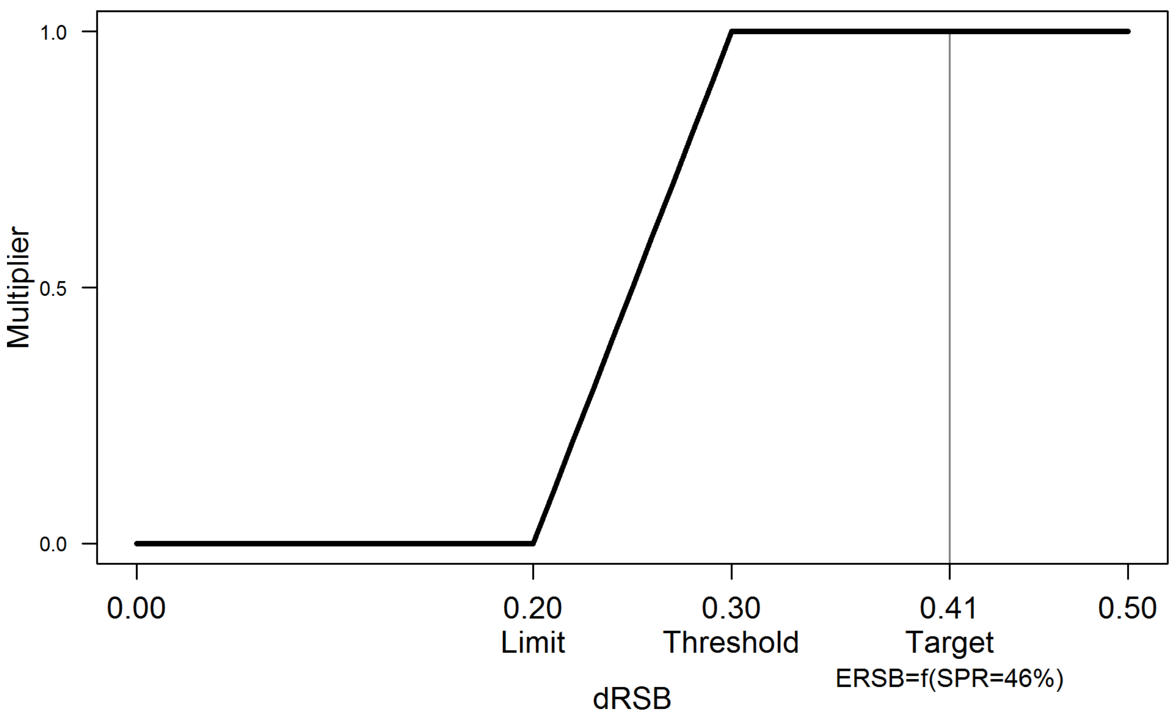
- Threshold is 30%
- Limit is 20%
- Adjust FI
- What are the appropriate threshold & limit?
- How should RSB be calculated?



Control Rule relationship with FI & ERSB

Equilibrium concepts (reference points)

- ERSB is a function of SPR and defines a **target**
- The **target** should be greater than the **threshold**
- The **threshold** is a status you want to be above most of the time
- **Limit** is a status you really want to avoid



Control Rule current status

$$RSB = \frac{SB_{current}}{SB_0}$$

- RSB is not a clear concept when there are regime shifts and changing biology
  - SB_0 is defined on static recruitment and biology
  - Not reflective of current conditions
  - Definition of SB_0 could result in poor stock status without fishing (e.g., reduction in size-at-age)

Control Rule current status

- For consistency with SPR and ERSB, RSB should be calculated using current conditions
- RSB should equal 1 if no fishing has occurred
  - $SB_{current}$ depends on past recruitment, thus denominator should also

Control Rule current status

Dynamic RSB and SB_0 (dRSB & dSB_0)

- The spawning biomass if no fishing occurred on current cohorts
  - Uses recent recruitment deviations and biology for the numerator and denominator
  - By definition, ranges from 0 to 1

$$dRSB = \frac{SB_{current}}{dSB_0}$$

Control Rule summary

- ERSB and SPR
  - Consistent equilibrium concepts that account for current conditions
  - Define a target
    - Can be used to help define threshold, limit
  - Can be calculated in “short” assessment models
- dRSB
  - A calculation for current RSB that is consistent with ERSB and SPR
  - dRSB is expected to fluctuate around the target ERSB

Control Rule decisions

- My suggestions
  - Control Rule scale fishing intensity (FSPR)
  - Use a 30:20 control rule, but with dRSB
  - Use a 25:15 control rule with dRSB for comparison
  - Possibly evaluate a case without a control rule

Control Rule additional thoughts

- We have an objective and performance metric related to the control rule
  - More about this later
- I would like to discuss dRSB with the SRB before evaluating too many control rules

From 2016 Assessment

Year	RSB	dRSB
2014	~41%	~33%
2015	~41%	~34%
2016	~42%	~36%
2017	~43%	~36%

Presenting results

Performance	25:15 Control Rule			30:20 Control Rule		
Metrics	SPR=30	SPR=40	SPR=50	SPR=30	SPR=40	SPR=50
Biological						
	XX	XX	XX	XX	XX	XX
	Probability	Probability	Probability	Probability	Probability	Probability
Fishery						
	XX	XX	XX	XX	XX	XX
	Probability	Probability	Probability	Probability	Probability	Probability
Note that some						
PM may not be						
reported						

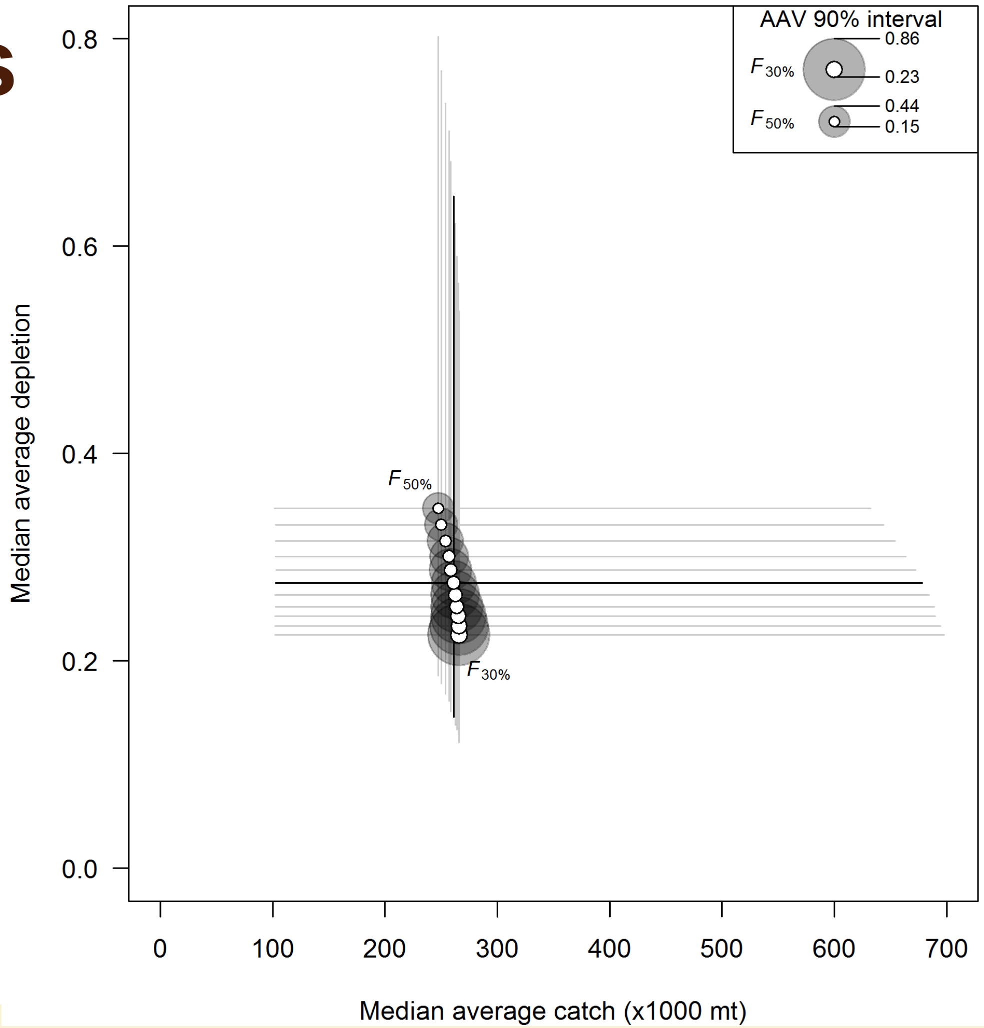
Presenting results example

- A table from Pacific hake MSE

	Long-term (2033-2042)				
	Perfect	F_{40}	F_{40}:0-500	F_{40}:0-375	F_{40}:180-375
Conservation					
Median average depletion	26%	39%	42%	45%	35%
Pr($B < B_{10\%}$)	2%	6%	5%	5%	19%
Pr($B_{10\%} \leq B \leq B_{40\%}$)	77%	48%	47%	44%	41%
Pr($B > B_{40\%}$)	21%	45%	49%	51%	41%
Yield					
Median average catch	242	199	203	216	233
Median AAV	32%	52%	41%	34%	19%
Pr(catch = 0)	1%	13%	12%	10%	0%
Pr(catch < 180)	44%	52%	50%	44%	21%
Pr(180 ≤ catch ≤ 375)	31%	27%	25%	56%	79%
Pr(catch > 375)	25%	21%	26%	0%	0%

Presenting Results

- A complicated figure to show the trade-offs (from Pacific hake)
- Trade-offs are typically between
  - Conservation
  - Yield
  - Stability in yield



Summary

- Framework
  - OM, Data, EM, Harvest Strategy
- Scenarios
  - Variability in simulations
- TCEY to sectors
- Fishing Intensity
- Control Rule