INTERNATIONAL PACIFIC
HALIBUT COMMISSION

A brief overview of Management Strategy Evaluation (MSE)

Agenda Item 3.6

IPHC-2019-MSAB013-INF01

13th Meeting of the Management Strategy Advisory Board (MSAB013)

Outline

- Brief history of harvest strategy and assessment at IPHC
- Models for fisheries management
- Strategy (MSE)
  - Objectives, Management Procedures, Simulation, Application
- Presenting and Interpreting Results

Some background on IPHC harvest policy

- Regulatory areas and closures
  - 3 month winter closure started in 1923
  - Closed area in Bering Sea to protect nursery area (1967)
- Size limit
  - 26 inches in 1940
  - Increased to 32 inches from 26 inches in 1973 for areas 2 and 3
  - All areas had a 32 inch size limit in 1974
- Harvest rates
  - Used since 1985, starting at 35% and decreasing since
- Conditional Constant Catch
  - A ceiling catch that is modified by a constant harvest rate when abundance is low
  - Not formally implemented
- Slow Up Fast Down (SUFD)
  - Utilized in 2001 as a formalization of the Commission process
  - 50% of recommended reduction
  - 33% of recommended increase
  - Suspended in 2011 due to a series of biomass declines

Stock assessment history

Years	Model	Era (Clark 2003)
Pre-1977	Yield, Yield-per-recruit, Simple stock-production models	Renaissance
1978-1981	Cohort analysis, coastwide, natural mortality (M)=0.2	
1982-1983	Catch-AGE-Analysis (CAGEAN, age-based availability), coastwide, M=0.2	Golden Age
1984-1988	CAGEAN, area-specific, migratory and coastwide, M=0.2	
1989-1994	CAGEAN, area-specific, M=0.2, age-based selectivity	
1995-1997	Statistical Catch-Age (SCA), area-specific, length-based selectivity, M=0.2	Modern Age
1998-1999	SCA, area-specific, length-based selectivity, M=0.15	
2000-2002	New SCA, area-specific, constant age-based selectivity, M=0.15	
2003-2006	SCA, area-specific, constant length-based selectivity, M=0.15	Postmodern
2006-2011	SCA, coastwide, constant length-based availability, M=0.15	
2012-present	SCA, coastwide, time-varying selectivity, ensemble model, move from catch advice to risk analysis	???

The start of MSE

- G. Morris Southward (1968)
- Simulation model with biology, fishery, and regulatory procedure components

Morris Southward in New Mexico ca. 1990.

REPORT OF THE
INTERNATIONAL PACIFIC HALIBUT COMMISSION

APPOINTED UNDER THE CONVENTION BETWEEN CANADA AND THE UNITED STATES OF AMERICA FOR THE PRESERVATION OF THE NORTHERN PACIFIC HALIBUT FISHERY

NUMBER 47

A SIMULATION OF
MANAGEMENT STRATEGIES
IN THE
PACIFIC HALIBUT FISHERY

BY

G. MORRIS SOUTHWARD

COMMISSIONERS:

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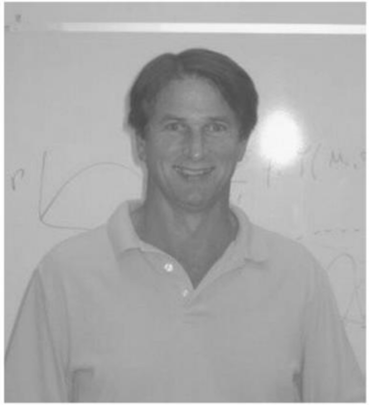
FRANCIS W. MILLERD
HAAKON M. SELVAR
WILLIAM M. SPRULES

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON
1968

Through the 1980’s

- Deriso and Quinn
- Focus on MSY
- Constant harvest rate policy

Terry Quinn teaching in Juneau ca. 2000.



Rick Deriso at IATTC, 2003.

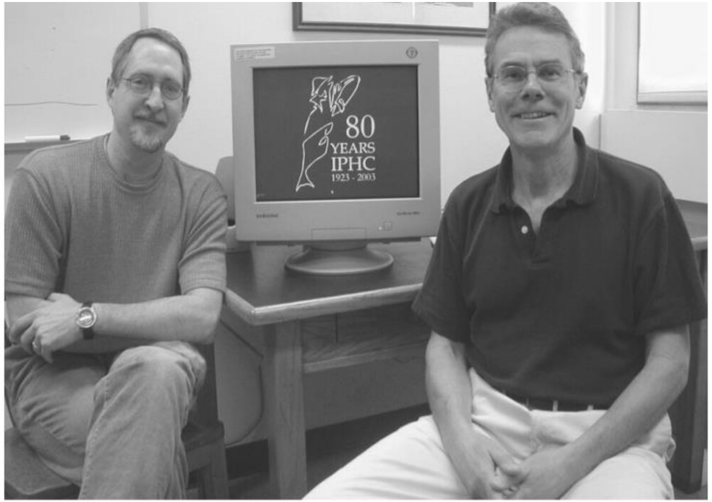
The Ana Parma decade

- Monte Carlo simulation of future stock trajectories (1991)
- Retrospective behavior and implications on harvest policy (1993)
- Optimal strategies with climate induced variability in recruitment (1996)
- Harvest rules in the face of uncertain assessments and decadal changes in productivity (2001)

Ana Parma in Argentina, 2002.

2000's: Clark & Hare

- Slow Up, Fast (Full) Down
- Constant Conditional Catch (CCC)
- Goal of the harvest policy
  - Obtain "Pretty Good Yield" while ensuring SBio never drops below observed historical minimum



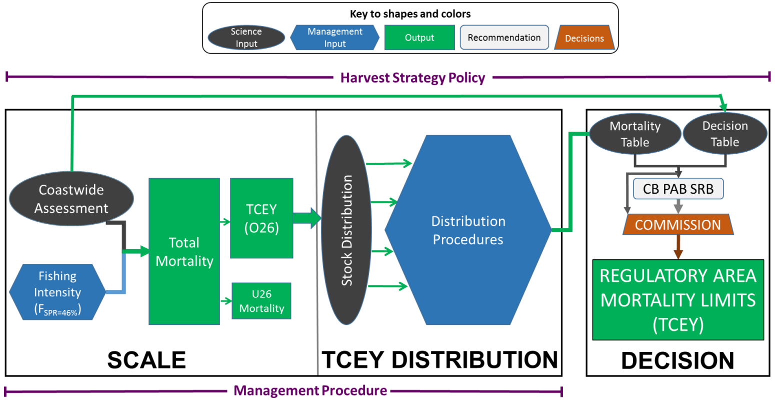
Steven Hare (left) and Bill Clark at IPHC, 2003.

Recent years

- Valero
  - Migration effects
  - Defining goals & objectives
  - Setting up stakeholder involvement
- Martell
  - Formalized meetings with stakeholders and managers
  - MSE education

Very recent years

- SPR-based management procedure
- Coastwide TCEY distributed to IPHC Regulatory Areas
- Account for mortality of all-sizes of Pacific halibut and from all sources
- Define clear objectives
  - harvest strategy policy document
- Define suitable reference points



Why am I interested in MSE?

- I used to think this was a fisheries model
- I wondered how management decisions were made
- What information was used for short-term decisions and long-term strategies
  - Data
  - Models

Use of models for fisheries management

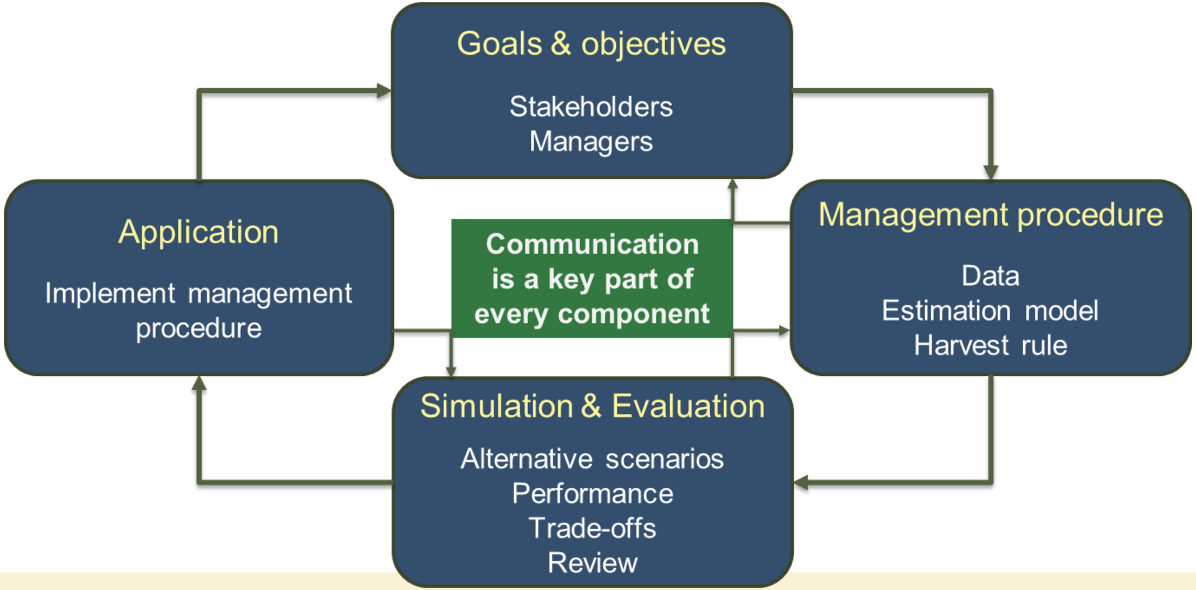
Conceptual Understanding	Strategic Planning	Tactical Decisions
Broad understanding	Long-term	Short-term
Forms underlying context for management planning	Policy goals	Operational objectives
Research	**MSE**	Harvest control rule

Management Strategy

FAO 2008. Technical guidelines for responsible fisheries. 4, Suppl. 2, Add. 1

Management Strategy Evaluation (MSE)

a process to evaluate harvest strategies and
develop a management procedure that is
robust to uncertainty and
meets defined objectives



Management Strategy Evaluation

"Using simulation to compare the relative effectiveness for achieving management objectives of different combinations of data collection schemes, methods of analysis and subsequent processes leading to management actions"

Punt et al. 2014
MSE: best practices

"Assessing the consequences of a range of management options and presenting the results in a way that lays bare the tradeoffs in performance across a range of management objectives."

Tony Smith
"Management Strategy Evaluation – the light on the hill"

Uncertainty and variability

An observation from a population is a random variable

There is inherent **variability** in the population (**irreducible**)

$$Var(X) = \sigma^2 = E\{[X - E(X)]\}$$

The **uncertainty** in the sample statistic goes to zero as sample size increases (**reducible)**

$$\sigma_{\bar{x}}^2 = \sigma^2/n$$

Variability translates into uncertainty

Uncertainty & variability in fisheries management

- Fish populations are inherently variable
- Sample sizes are small compared to the population numbers
- Uncertainty can be large

2019 Hake Assessment (Berger et al)

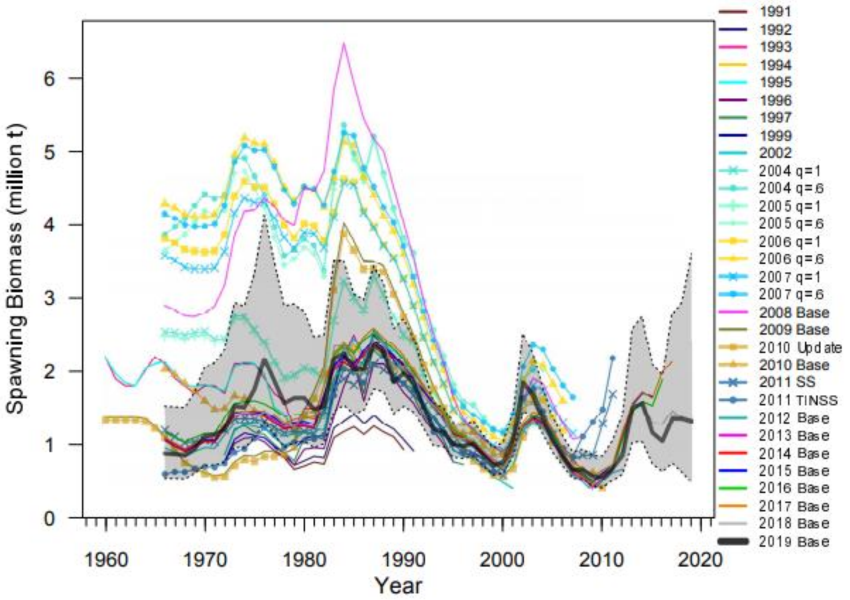


Figure 71. Summary of historical Pacific Hake assessment estimates of spawning biomass. Estimates are MLEs or MCMC medians depending on the model structure. Shading represents the approximate 95% confidence range from the 2019 base model.

Types of uncertainty and variability

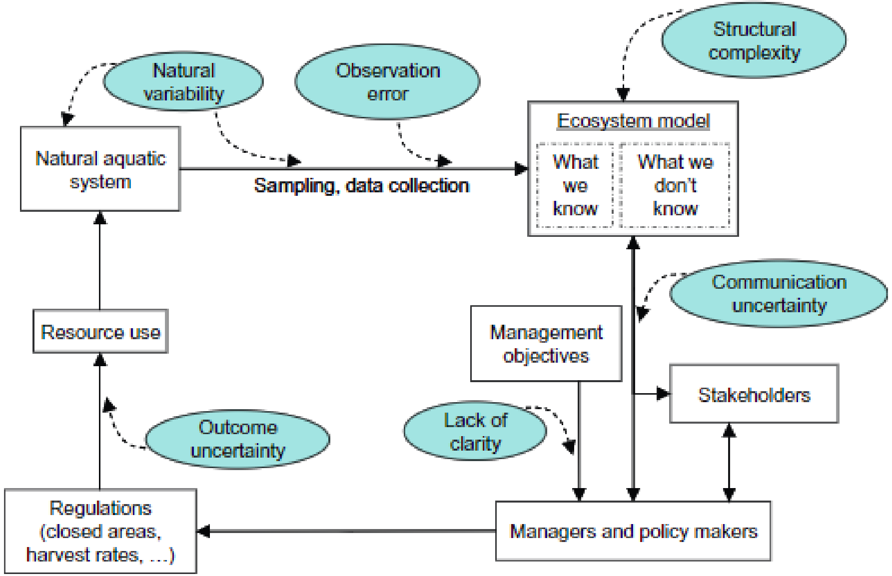
- Process variation
  - Natural variability in processes such as natural mortality, recruitment, selectivity, etc.
- Parameter uncertainty
  - Uncertainty in estimated parameter values due to variability and sampling in data
- Model and assessment uncertainty
  - Due to model structure and assumptions
  - Estimation of values used to inform harvest rule
- Outcome & Implementation uncertainty
  - Departure from the management strategy
  - Accuracy of meeting the established target

Punt et al (2014): MSE best practices

http://sedarweb.org/docs/page/addressing-uncertainty-in-fisheries-science-and-management-report.pdf

Additional types of uncertainty

- Inadequate communication
  - Between and within scientists, managers, and stakeholders
  - "When communication is ineffective, information is lost"
- Unclear management objectives
  - Aligning the model with management objectives

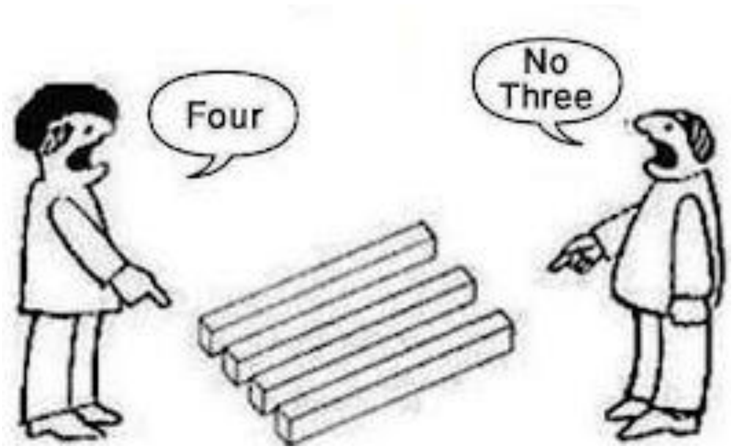


Link et al 2012. Prog. Oceanogr.

Another type of uncertainty

Perception uncertainty

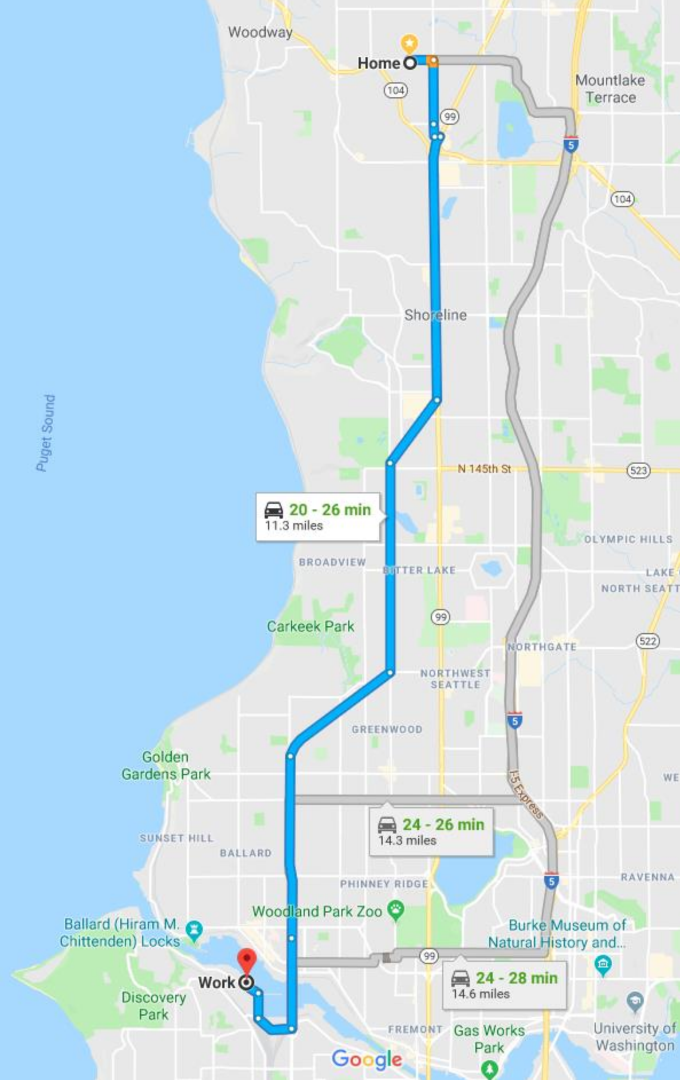
- Different views of the fish population
  - Fisheries vs. surveys
  - Local vs. stock abundance
- Important to realize this
- Can learn from different views



www.debate.org

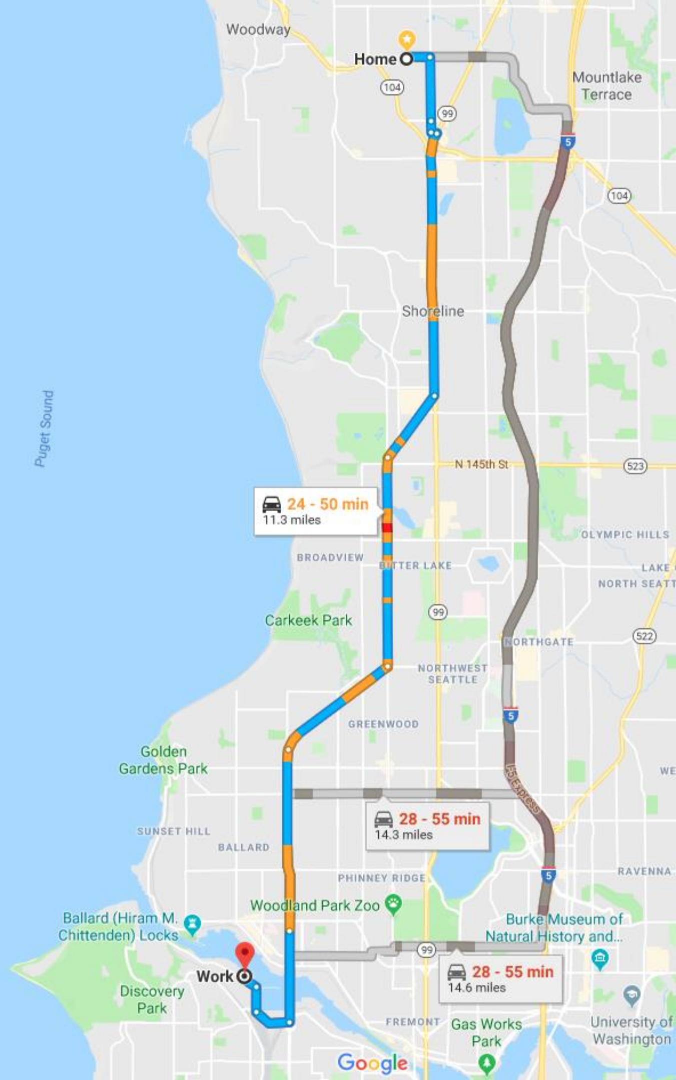
Strategic Planning

- Develop a strategy that meets objectives and is robust to variation
  - Normal (default) commute to work
- Observations are variable
  - Construction
  - Weather
  - Traffic



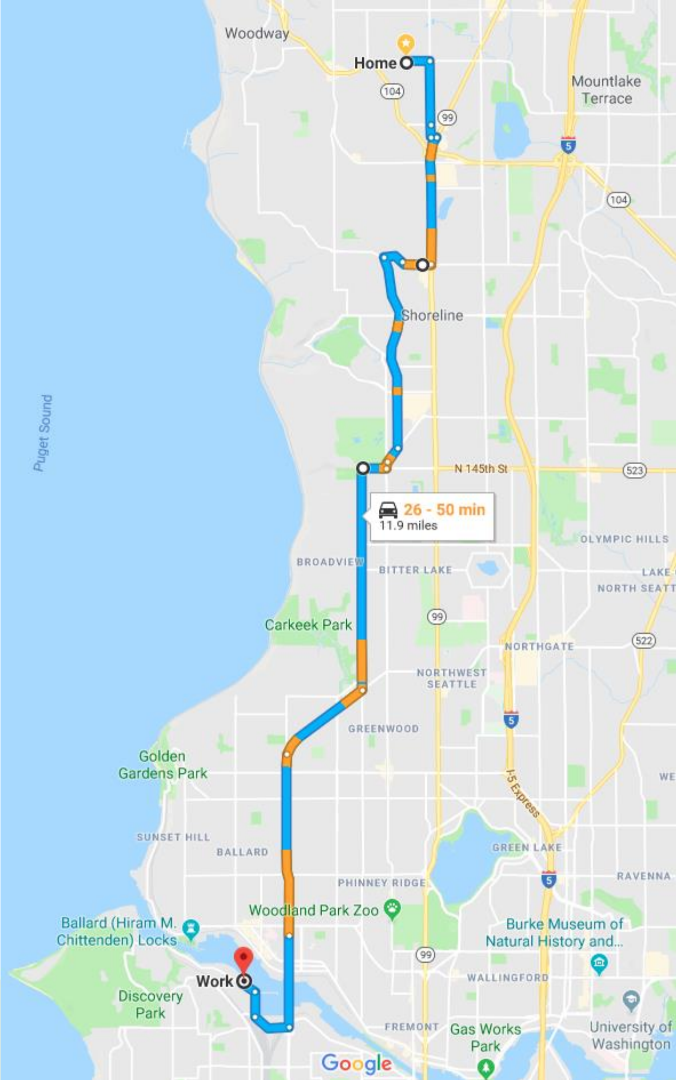
Strategic Planning

- However, there are factors to consider and you may have some information (or learn it over time)
  - Time of day that you leave
  - Typical bottlenecks along the route
  - Alternatives due to weather



Strategic Planning

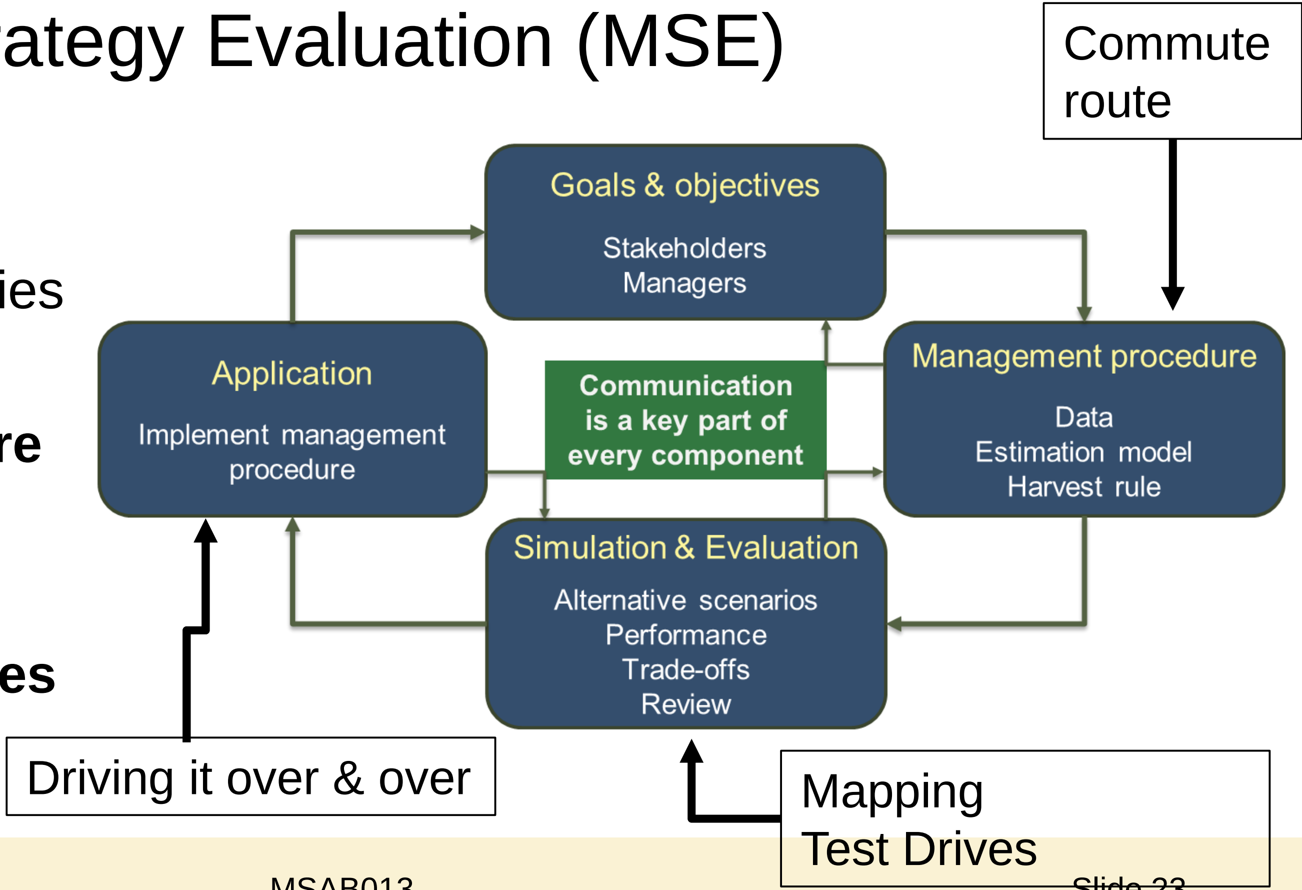
- So, you develop your default route (procedure) based on objectives
  - Minimize time
  - Avoid bottlenecks along the route
  - Avoid street lights
  - As few turns as possible
  - Minimal decision making
  - Minimize the range of time it takes
  - Minimize distance



Strategic Planning

Management Strategy Evaluation (MSE)

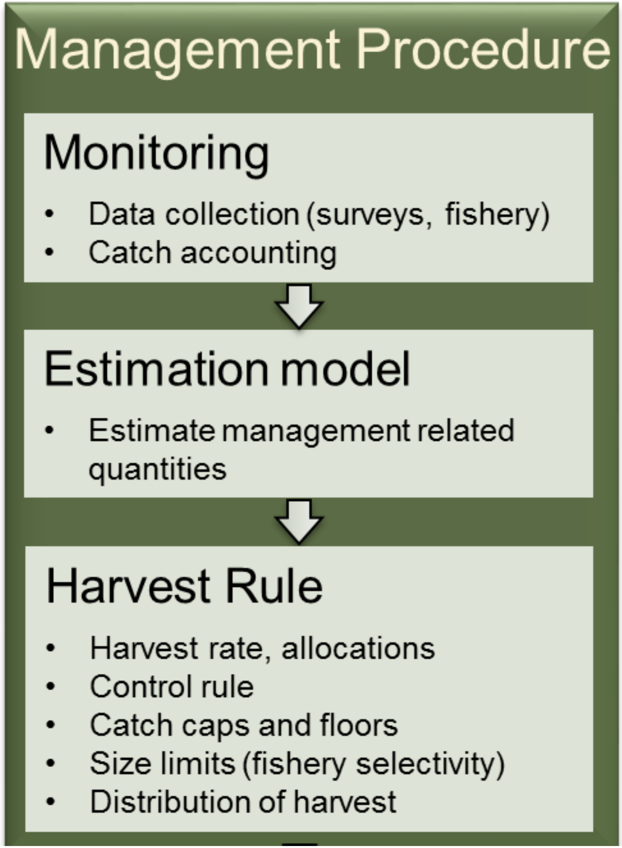
a process to **evaluate** harvest strategies and develop a **management procedure** that is **robust** to **uncertainty** and **meets defined objectives**



Strategic Planning

Evaluate Management Procedures

- Meet defined objectives
- Robust to variability and uncertainty
- Uses an operating model (OM)
- A fishing mortality rate is often used

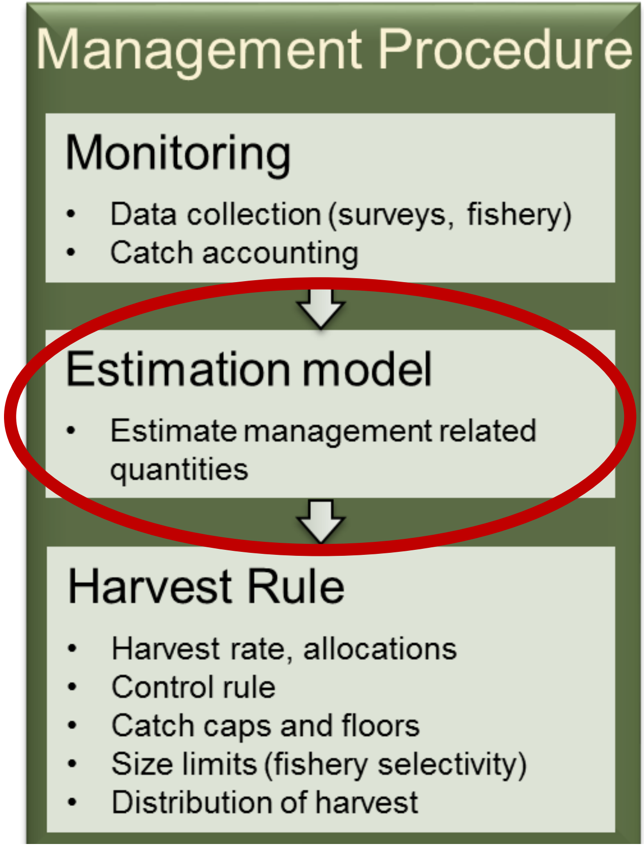


Tactical Decision-making

- During the commute, you can see a short distance ahead and you may listen to traffic reports
- Based on those data, you may make tactical decisions
  - If a bus in the right lane, you may move to the left lane
  - If see flashing lights or hear a traffic report, you may choose an alternate route
- The strategy can define tactics
  - Applying the strategy
- Or you may try to “beat the commute”
  - Deviate from the strategy

Tactical Decision-making

- The tactical decision-making process is a part of the strategy
  - Use a specific model that incorporates data in a specific way
  - Purpose is to estimate management quantities
- A specific catch limit is often the output



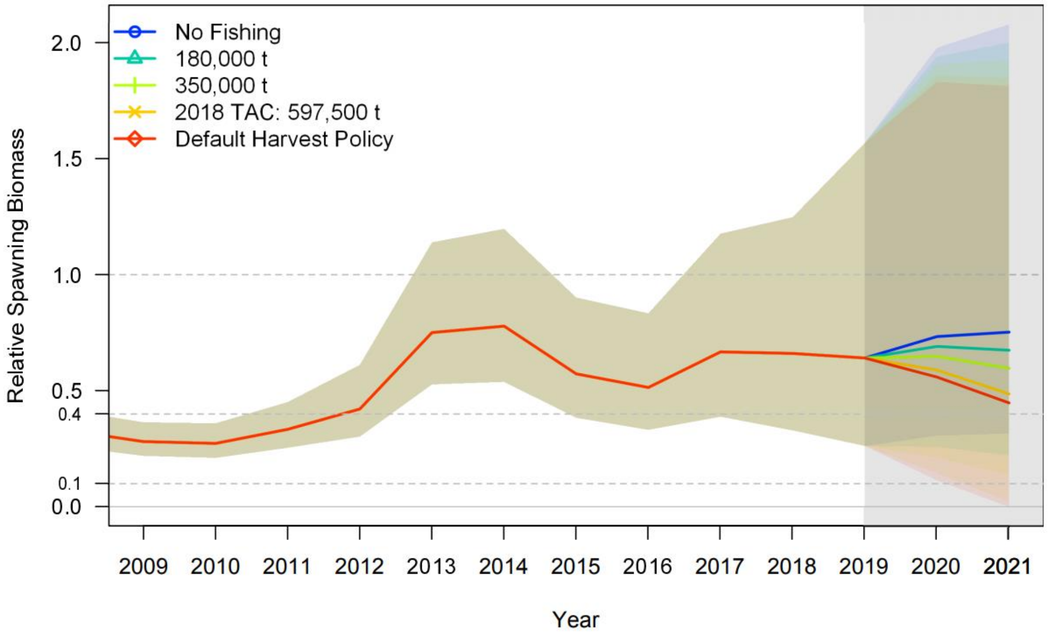
Tactical Decision-making

Stock assessment (short-term forecast)

- Prediction models
- Fishery data
- Fishery-independent data
- Forecast only as far as the data allow

1. Uses recent data to apply the strategy
2. Decision-makers may deviate from the strategy

2019 Pacific Hake Assessment (Berger et al)



My commute and fisheries management

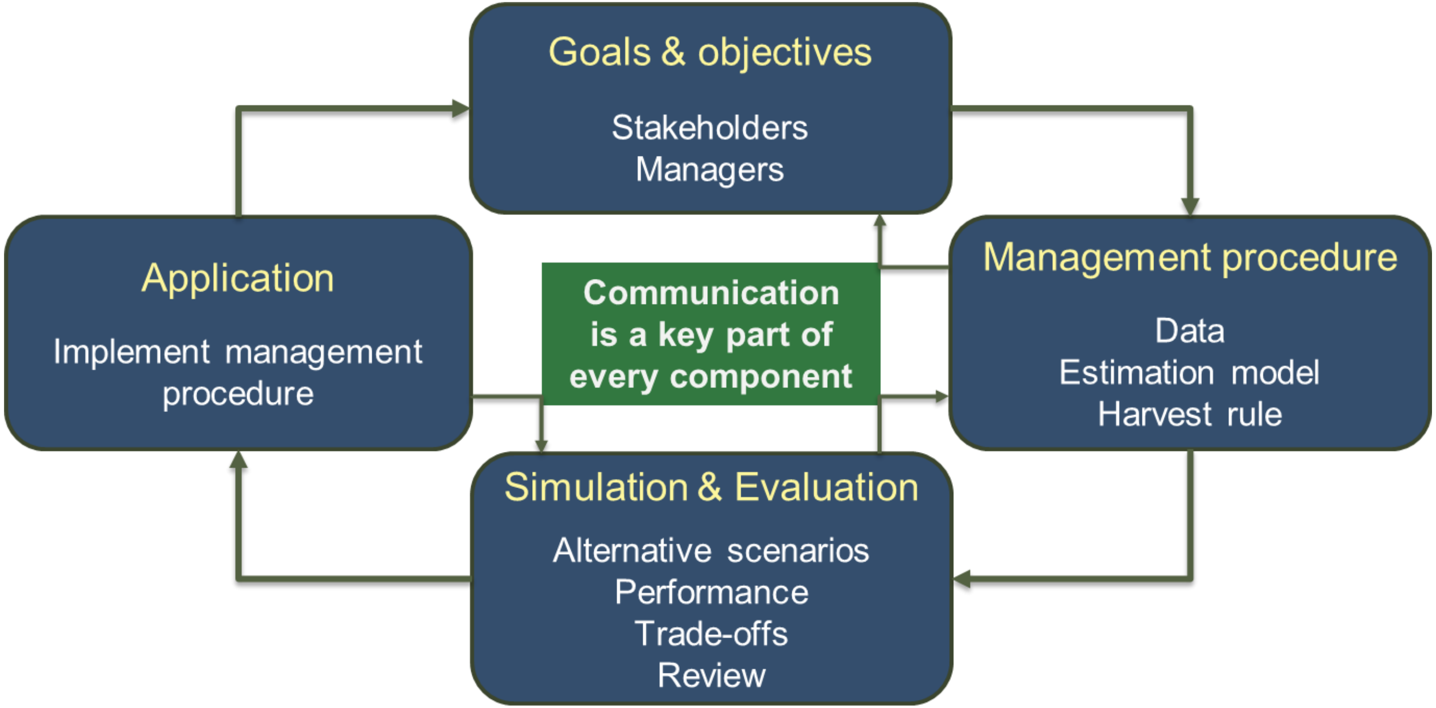
- I have a strategy with specific tactics based on observations
  - Route and lanes to be in
  - Default fishing mortality rate (F_{SPR}) and control rule
- I have limits that I must stay within (laws)
  - Shall not overfish
- I'm applying my strategy and making tactical decisions
  - Some decisions may increase my commute time
  - **On average**, my strategy should meet my objectives

Updating the strategy

Is it better to stick to the strategy no matter what, or try to beat the strategy; or when to update the strategy?

- Objectives may not be met if deviate from the strategy
- Recent observations, updated knowledge, and upgraded technology may provide insight to updating the strategy

MSE is a process



An adaptive stakeholder guided process

MSAB	**Review**	work that has been done
MSAB	**Consult**	with stakeholders
MSAB, SRB	**Refine**	goals, objectives, management procedures
MSAB, SRB	**Change**	inputs and methods
MSAB to others	**Report**	results from simulations and evaluations
All groups	**Choose**	best performing management procedures

An adaptive stakeholder guided process

Review	work that has been done
Consult	with stakeholders
Refine	goals, objectives, management procedures
Change	inputs and methods
Report	results from simulations and evaluations
Choose	best performing management procedures

REPEAT

Goals and objectives

- This is a very important step
  - Requires input from stakeholders and managers
  - Goals can be broad and aspirational
  - Ultimately need to state **measurable objectives**
    1. An outcome (what you want)
    2. A time frame (when you want the outcome)
    3. A probability (tolerance for failure)

Fishery objectives

Stakeholders
Managers

Purpose of an MSE

- Design a fishery management system to meet these objectives
- Long-term strategic thinking
  - On average, what performs best
  - Aware of getting to long-term
- However, objectives are usually in conflict
  - Need to examine and evaluate trade-offs between objectives

- Without objectives, there is nothing to evaluate against

From Goals to Performance Metrics

Goal

Biological Sustainability

General Objective

Avoid critical stock sizes

Means objective to Ends objective

Measurable Objective

Maintain a minimum spawning stock biomass

1. Outcome: Spawning stock is less than 0.20B

Thres

Now c

Metri

sed as risk

tolerance

Performance Metric

Probability that the spawning stock is less than 20% of B_0 over a simulated 10 year period, after 100 simulated annual cycles

Management Procedure

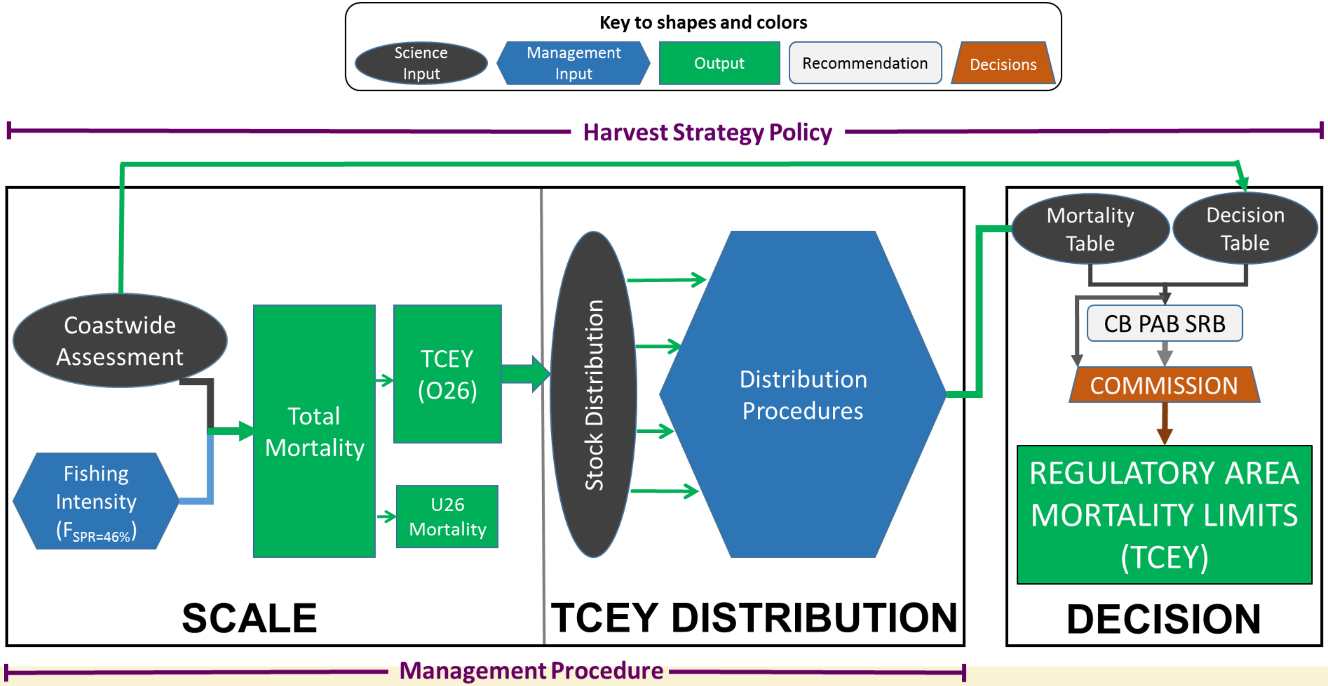
- A management procedure consists of things we control
  - Data collection
  - Assessment models
  - Harvest setting and rules
- No “perfect” choice
  - Some choices meet objectives more closely
- Can be simple or complex
- Stakeholders and managers help determine procedures to be tested

Management procedure

Data
Estimation model
Decision-rule

Management Procedure at IPHC

- SPR-based harvest strategy policy
- Distribute catch limits to IPHC Regulatory Areas



Simulation and Evaluation

- Testing alternative management procedures against various scenarios
  - An **operating model** simulates a population
    - Admit uncertainty in natural systems (alternative hypotheses)
  - The operating model feeds into the management procedure to determine catch advice
  - **Performance metrics** allow for evaluation
    - Developed from objectives and typically related to
      1. Conservation
      2. Yield
      3. Stability in yield

Simulation & Evaluation

Alternative scenarios
Performance
Trade-offs
Review

Operating model vs. Management procedure

Population Dynamics

Operating model
Stock-recruitment relationship
Natural mortality
Selectivity (time-varying?)
Movement and life history
Growth (time-varying?)
Predator-prey drivers
Environmental drivers
Discard mortality (by gear types?)
Recruitment forecasting

We don’t (or choose not to) control these

We make assumptions

We may have data to help

Choices

Management Procedure
Survey index (frequency, sample size?)
Biological data (frequency, samples?)
Estimation models (simple or complex)
Assessment frequency
Harvest control rule
- Shape of rule
- Choice of reference points
Biomass reference points
Fishing reference points

We make these choices

Closed-loop simulation

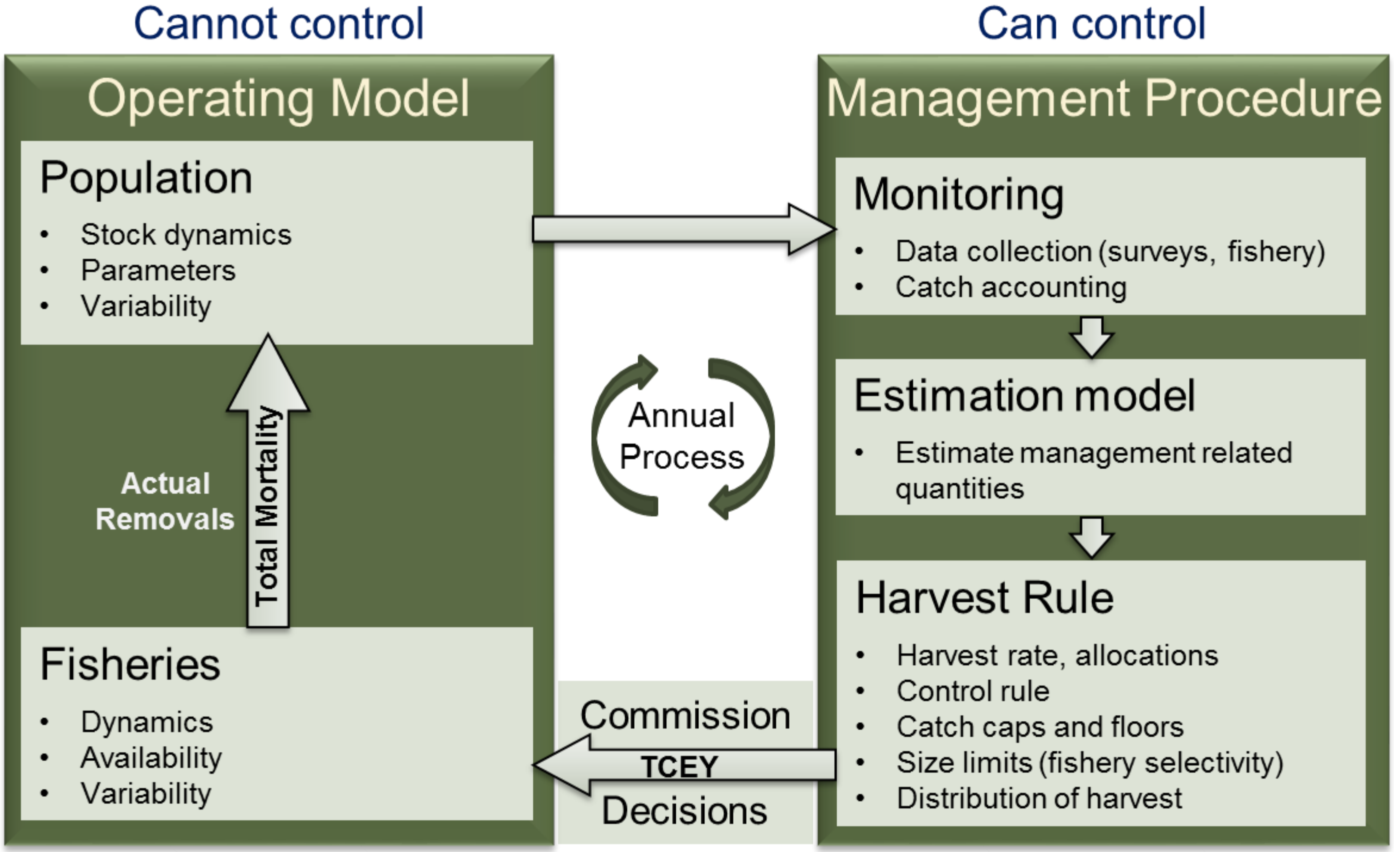
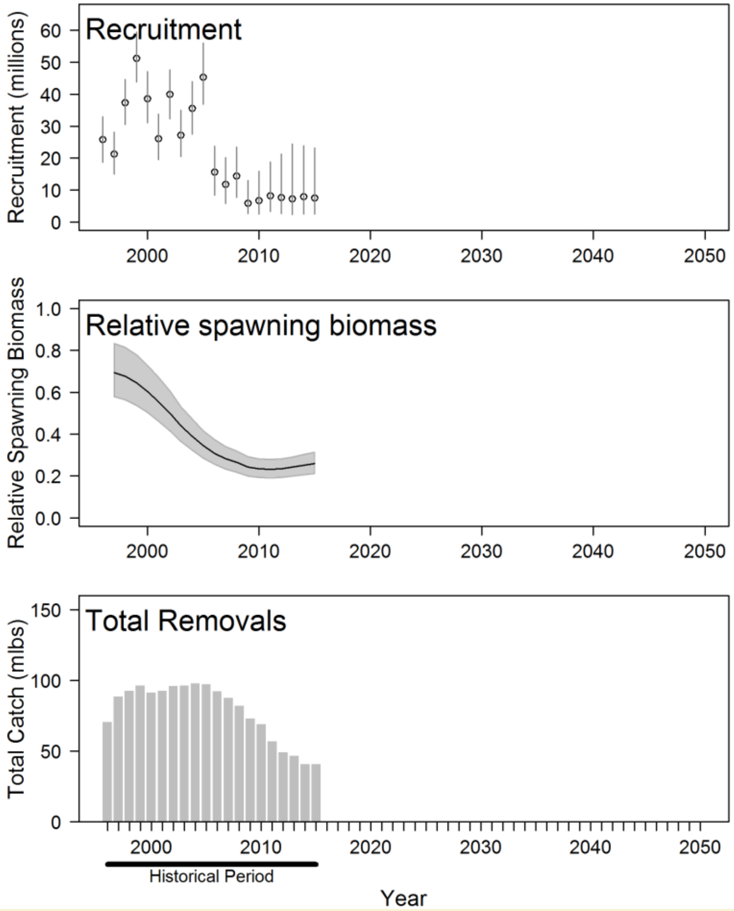


Illustration of MSE simulations (1)

- Start with an operating model



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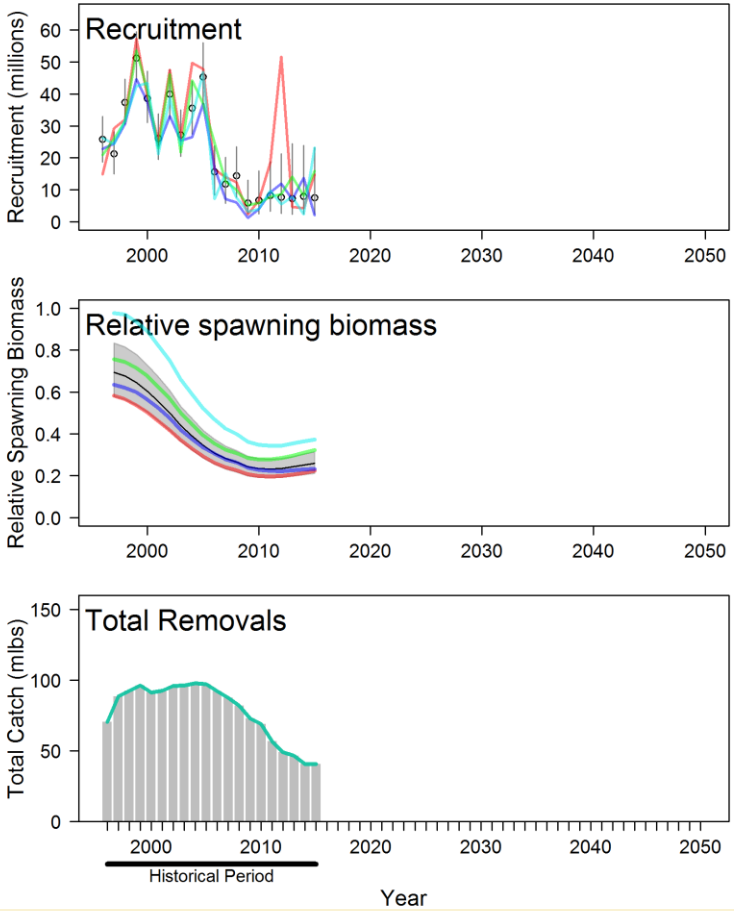
Hypothetical example. Do not use for management.

Illustration of MSE simulations (2)

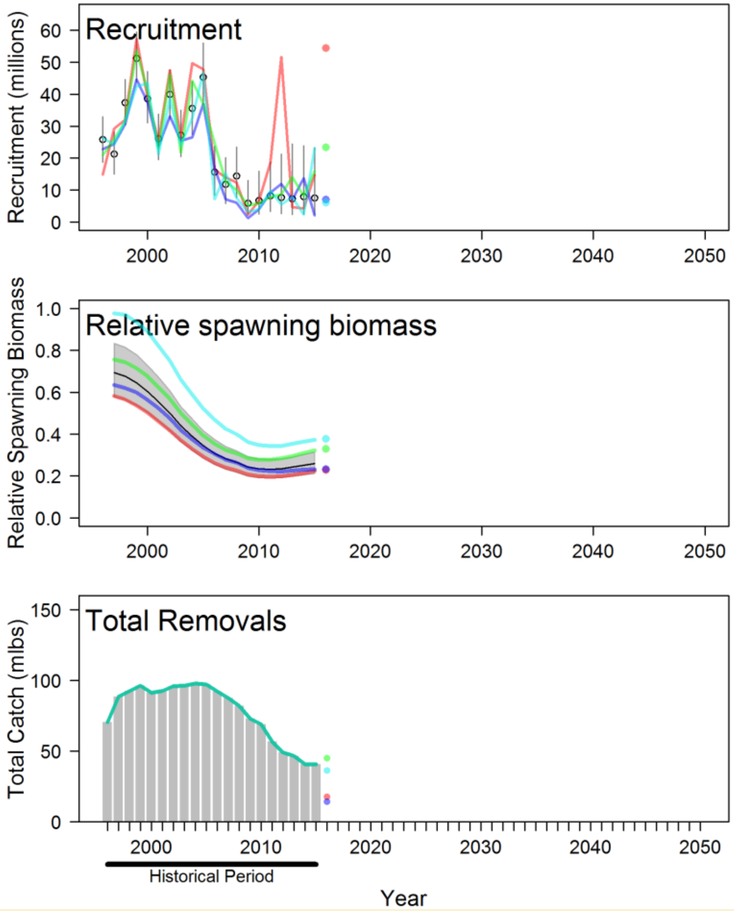
- Start with an operating model
- Introduce variability in the operating model
  - Catch history is assumed known



Hypothetical example. Do not use for management.

Illustration of MSE simulations (3)

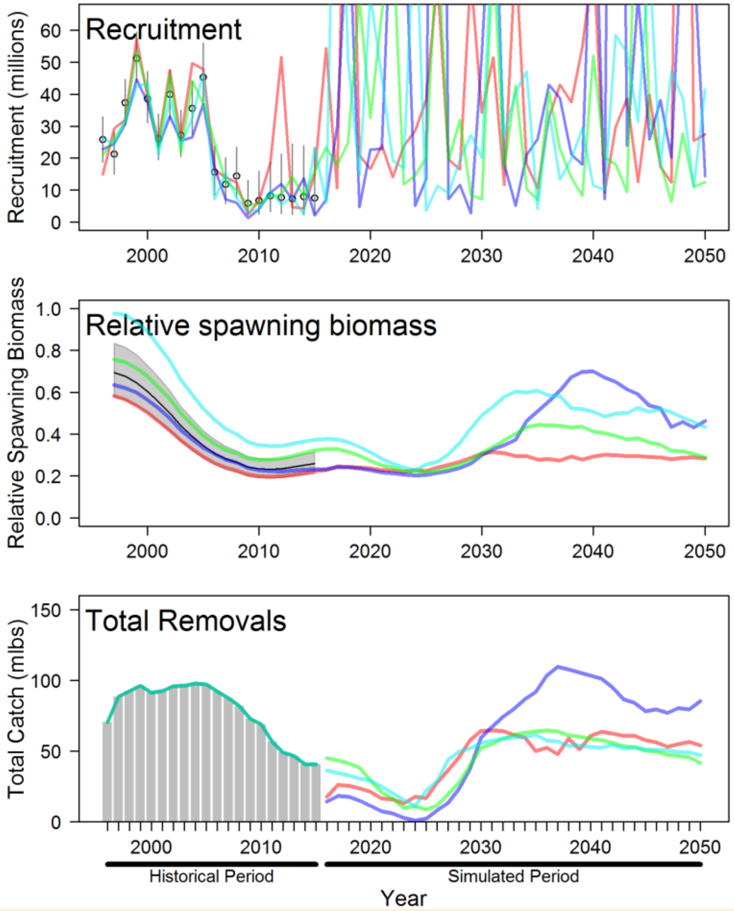
- Start with an operating model
- Introduce variability in the operating model
  - Catch history is assumed known
- Project one year and determine total removals from management procedure



Hypothetical example. Do not use for management.

Illustration of MSE simulations (4)

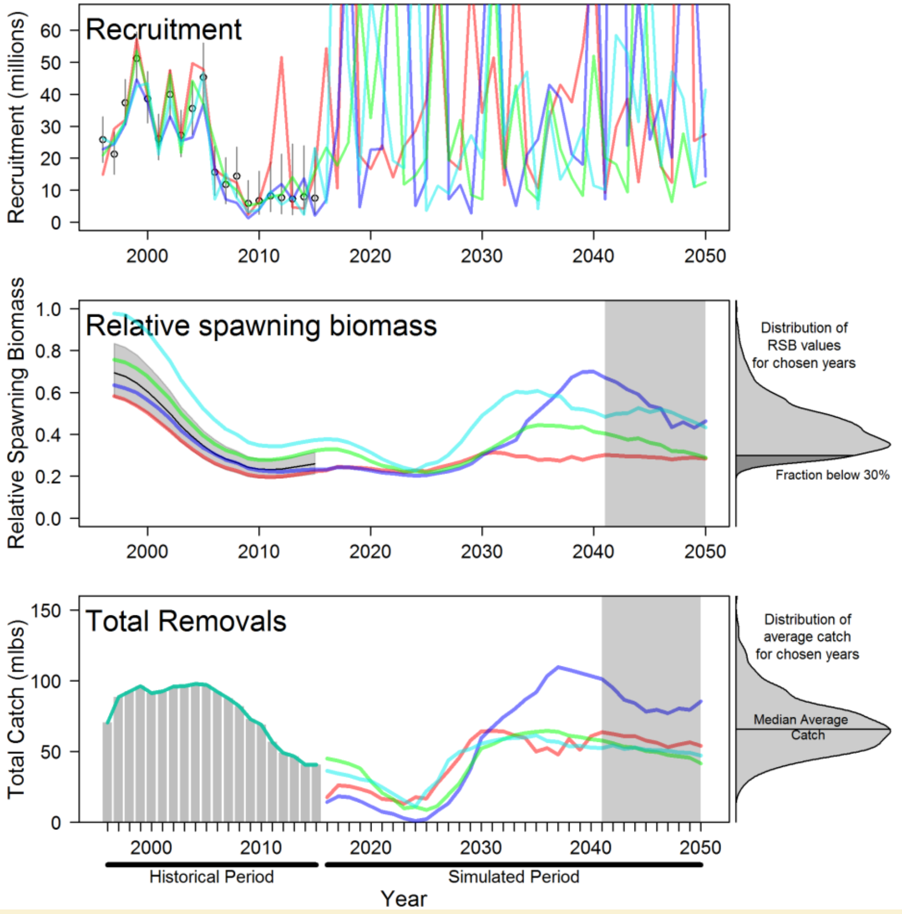
- Start with an operating model
- Introduce variability in the operating model
  - Catch history is assumed known
- Project one year and determine total removals from management procedure
- Repeat this for many years
  - The future is uncertain



Hypothetical example. Do not use for management.

Illustration of MSE simulations (5)

- Start with an operating model
- Introduce variability in the operating model
  - Catch history is assumed known
- Project one year and determine total removals (MP)
- Repeat this for many years
  - The future is uncertain
- Do this for many random trajectories
- Summarize performance metrics over a specified period



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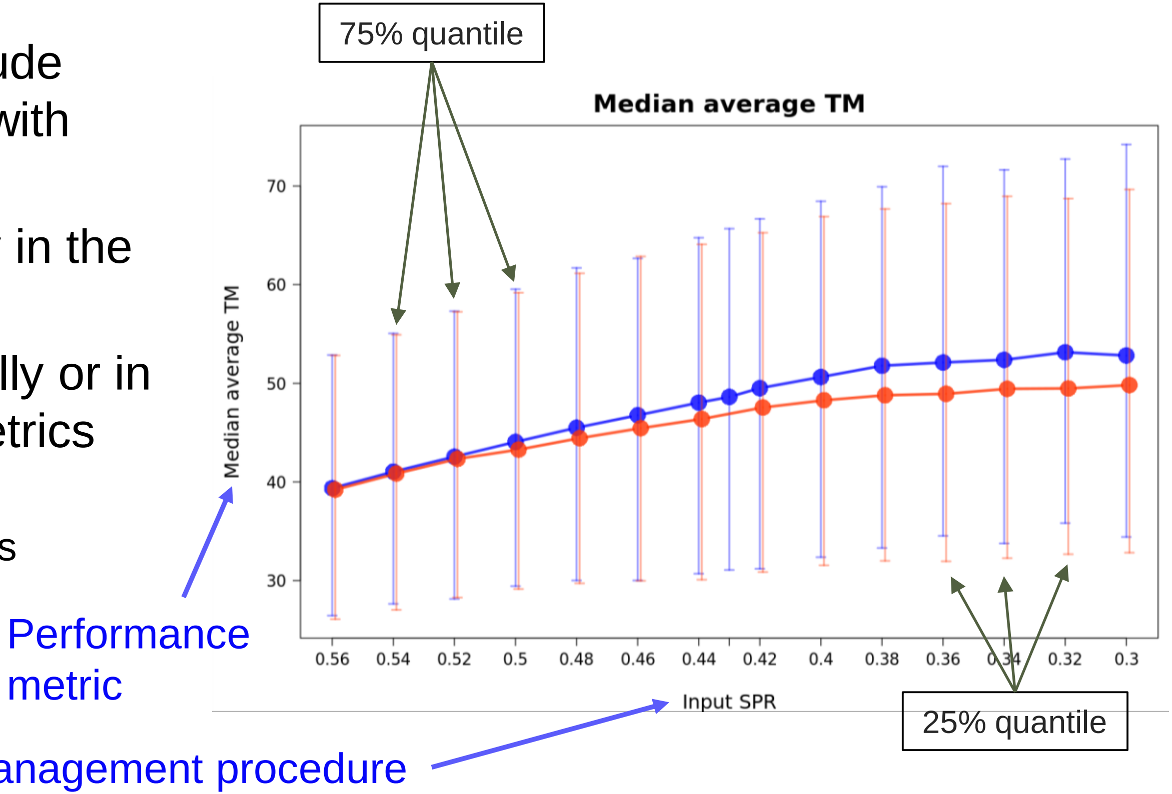
Hypothetical example. Do not use for management.

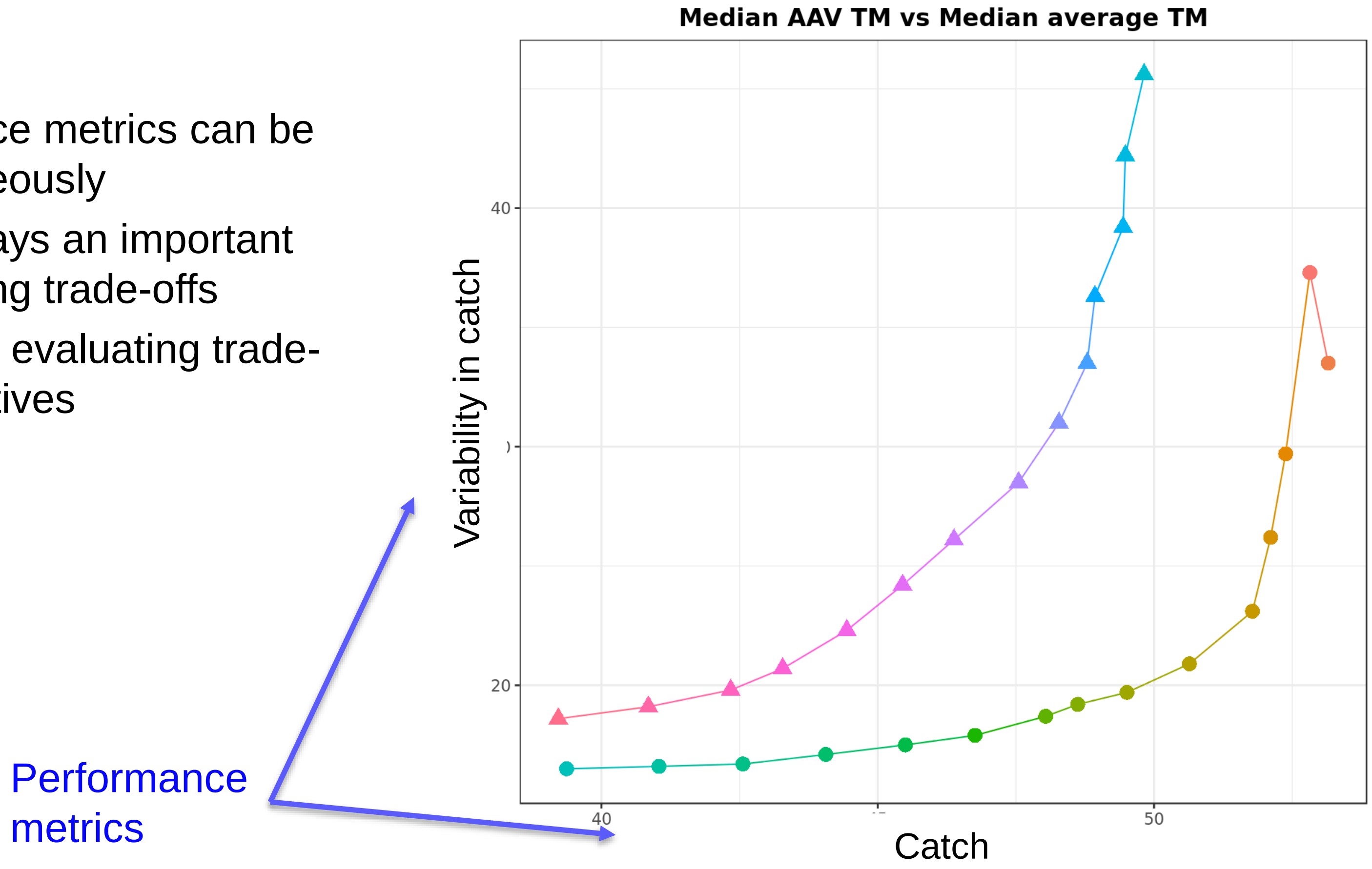
Presenting results

- Closed-loop simulations include many simulated trajectories with uncertainty
- This translates to uncertainty in the outputs (i.e., catch)
- Summarize outputs graphically or in tables using performance metrics
  - Probabilities
    - Probability Yield < 40Mlbs
  - Statistics of Interest
    - Median average catch



Trade-offs

- Multiple performance metrics can be displayed simultaneously
- Uncertainty also plays an important role in understanding trade-offs
- Users participate in evaluating trade-offs between objectives



Ranking management procedures (strategy)

Management Procedure														
Input Control Rule	30:20													
Constraint	maxChange Both		maxChange Up		slowUp FastDown		slowUp FullDown		Cap80		Cap60		multiYear	
Input SPR	46%	40%	46%	40%	46%	40%	46%	40%	46%	40%	46%	40%	46%	40%
Performance metrics														
Biological Sustainability (Long-term)														
P(any dRSB_y<20%)	0.02	0.02	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Fishery Sustainability (medium-term)														
P(all AAV > 15%)	0.04	0.05	0.27	0.35	0.07	0.14	0.13	0.26	0.58	0.61	0.45	0.48	0.14	0.26
Median average TM	46.1	49.5	44.0	45.3	45.0	49.5	44.7	49.3	46.4	50.7	46.1	50.0	46.5	50.5
Rankings (lower is better)														
Meet biological objective?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Meet stability objective?	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	Yes	No
Maximum catch (TM)	9	4	14	11	12	5	13	6	8	1	10	3	7	2
Overall Ranking	4	1	—	—	5	2	6	—	—	—	—	—	3	—

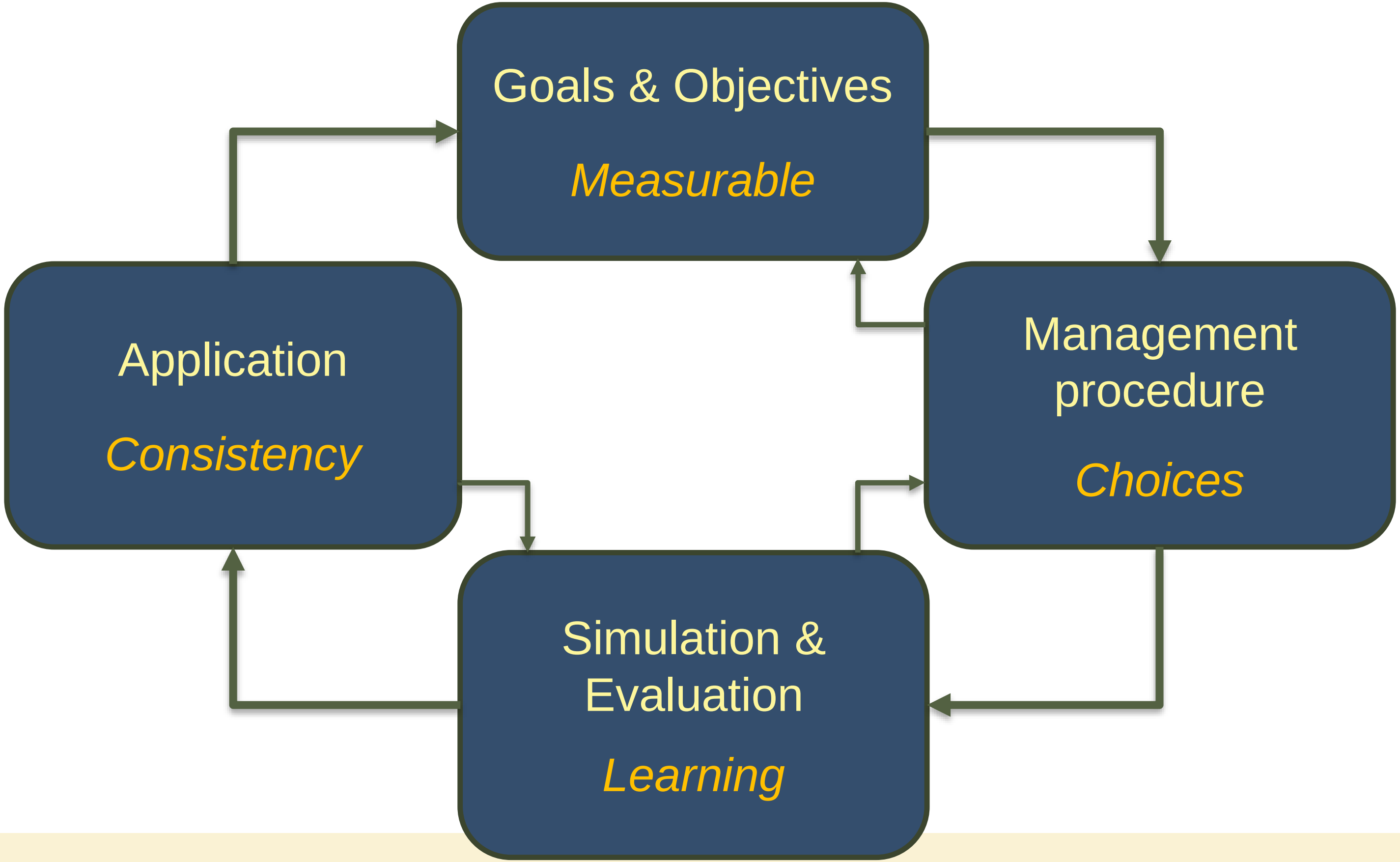
Consistent application and feedback

- Implement a management procedure
- Learn from real-time performance
  - Feedback comes from stock and fishery monitoring data
  - Continue process to make sure staying on course
- Not an annual process
  - Likely longer than a year to get to Application
  - Once applied, the annual process is to consistently apply the management procedure
- Implementation variability can be simulated in the annual decision making process

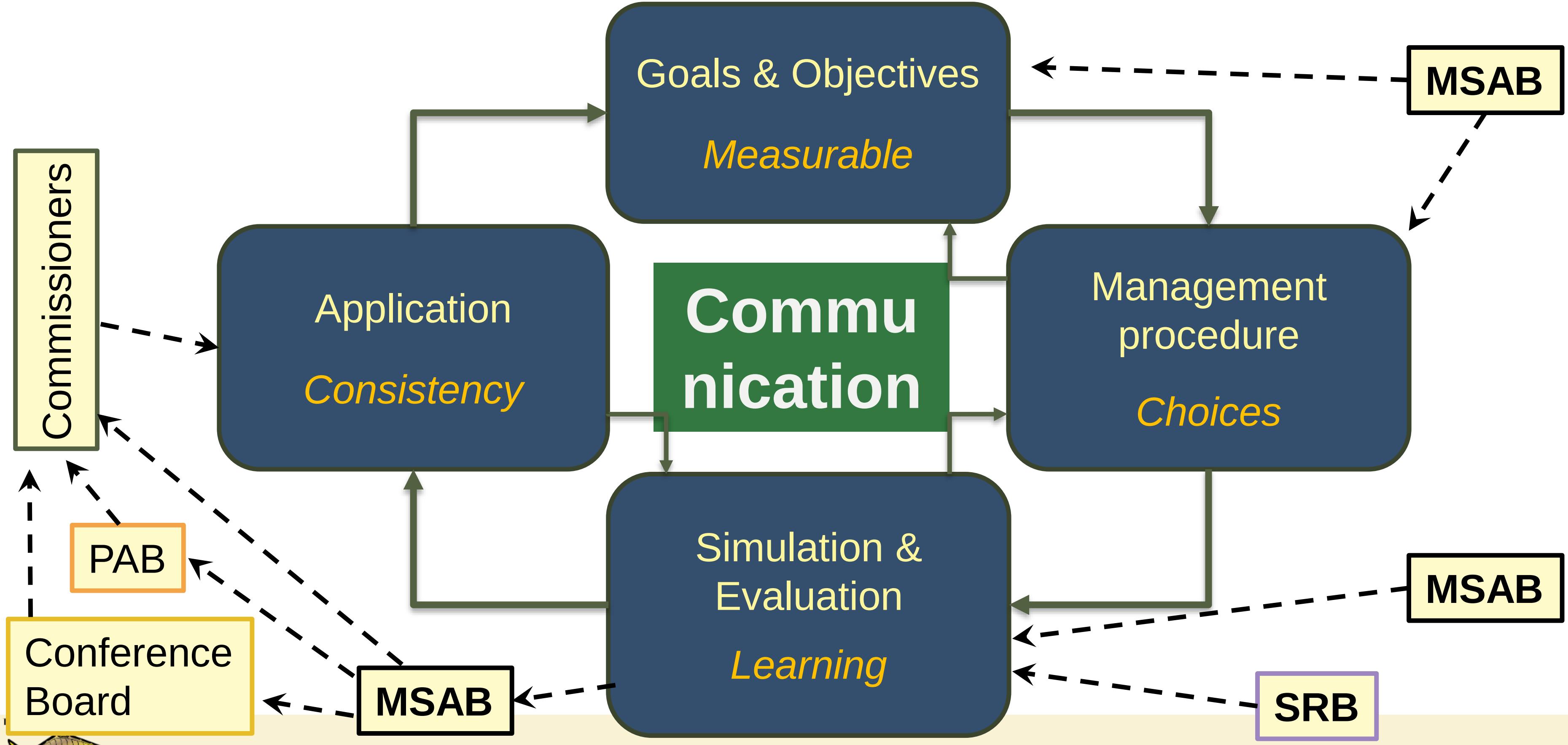
Application

Implement management procedure

MSE is a process (not a one-time product)



MSE is a process (not a one-time product)



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Similar table from assessment

IPHC harvest decision table (tactical)

2018 Alternative	No removals	Reference: SPR=46%
Total removals (M lb)		
TCEY (M lb)		
Fishing intensity		
Fishing intensity interval		

Stock Indicators	Stock Trend (spawning biomass)	in 2019	is less than 2018	a
			is 5% less than 2018	b
		in 2020	is less than 2018	c
			is 5% less than 2018	d
		in 2021	is less than 2018	e
			is 5% less than 2018	f
	Stock Status (Spawning biomass)	in 2019	is less than 30%	g
			is less than 20%	h
		in 2020	is less than 30%	i
			is less than 20%	j
		in 2021	is less than 30%	k
			is less than 20%	l
Fishery	Fishery Trend (TCEY)	in 2019	is less than 2018	m
			is 10% less than 2018	n
		in 2020	is less than 2018	o
			is 10% less than 2018	p
		in 2021	is less than 2018	q
			is 10% less than 2018	r
	Fishery Status (Fishing intensity)	in 2018	is above $F_{46\%}$	s

Benefits

Risk

The harvest decision table

Tactical application of interim MP

2019 Alternative			No fishing mortality					Status quo		*Reference SPR=46%*								
Total mortality (M lb)			0.0	11.7	21.8	31.8	37.6	39.0	40.4	41.8	43.1	44.3	45.5	46.8	48.3	49.9	61.8	
TCEY (M lb)			0.0	10.0	20.0	30.0	35.8	37.2	38.6	40.0	41.3	42.5	43.7	45.0	46.5	48.1	60.0	
2019 Fishing intensity			$F_{100\%}$	$F_{78\%}$	$F_{64\%}$	$F_{54\%}$	$F_{49\%}$	$F_{48\%}$	$F_{47\%}$	$F_{46\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{42\%}$	$F_{41\%}$	$F_{40\%}$	$F_{34\%}$	
Fishing intensity interval			--	56-87%	41-76%	31-67%	27-63%	26-62%	25-61%	25-60%	24-59%	23-59%	23-58%	22-57%	22-56%	21-55%	17-49%	
Stock Trend (spawning biomass)	in 2020	is less than 2019	1	3	26	60	77	81	84	87	90	92	93	95	96	97	>99	a
		is 5% less than 2019	<1	<1	1	10	26	30	34	37	39	41	43	45	48	50	78	b
	in 2021	is less than 2019	1	7	41	75	90	93	94	96	97	98	98	99	99	99	>99	c
		is 5% less than 2019	<1	1	11	42	57	61	65	69	73	77	80	83	87	90	99	d
	in 2022	is less than 2019	1	12	51	82	93	94	96	97	98	98	99	99	99	>99	>99	e
		is 5% less than 2019	<1	3	28	58	76	79	83	86	88	90	92	93	95	96	>99	f