Interpreting MSE Results and MSE Application Case Studies

May 20th, 2019 – Second PBF MSE Workshop

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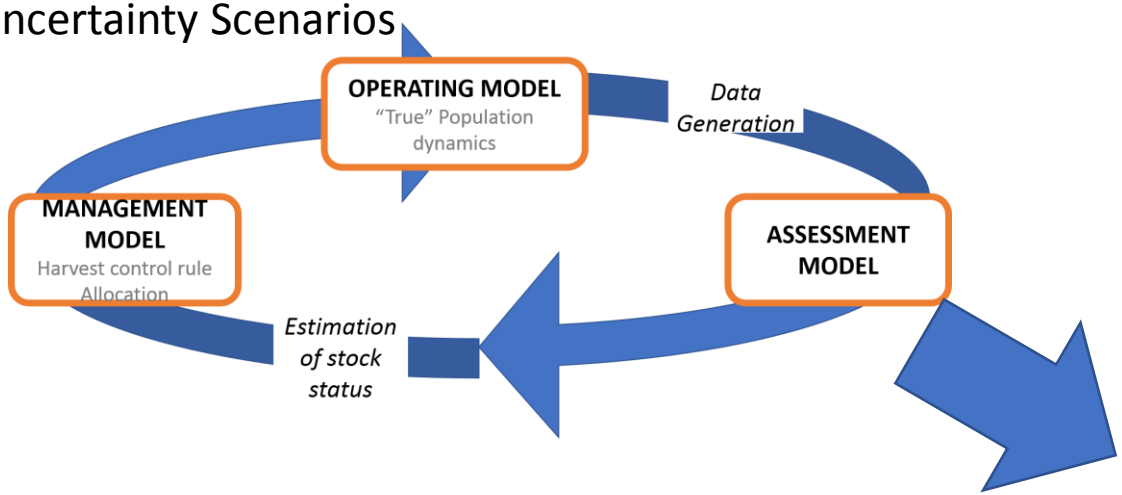
MSE

Many Harvest Control Rules
Many Uncertainty Scenarios



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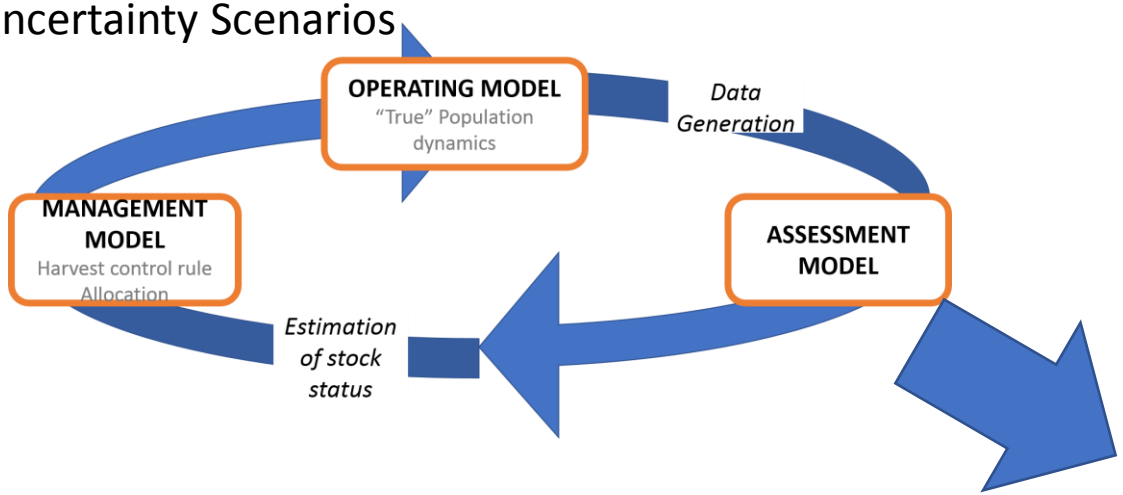

			FPO			IPLL			IPPI			IPNI		
Output Control	HS	HCR	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75
TAC	1	1	0.89	1.00	0.79	0.53	0.98	0.05	0.73	0.99	0.36	0.65	1.00	0.60
TAC	1	4	0.92	1.00	0.82	0.56	0.98	0.05	0.77	1.00	0.40	0.68	1.00	0.65
TAC	1	6	0.93	1.00	0.82	0.57	0.98	0.06	0.78	1.00	0.41	0.69	1.00	0.65
TAC	1	7	0.85	1.00	0.91	0.62	0.99	0.20	0.74	1.00	0.61	0.70	1.00	0.80
TAC	1	10	0.92	1.00	0.93	0.68	0.99	0.28	0.82	1.00	0.68	0.77	1.00	0.85
TAC	1	12	0.95	1.00	0.94	0.72	0.99	0.32	0.86	1.00	0.72	0.82	1.00	0.88
TAC	1	13	0.87	1.00	0.97	0.69	1.00	0.49	0.78	1.00	0.82	0.77	1.00	0.94
TAC	1	15	0.92	1.00	0.97	0.76	1.00	0.57	0.85	1.00	0.85	0.84	1.00	0.95
TAC	3	1	0.84	1.00	0.72	0.48	0.96	0.02	0.66	0.99	0.26	0.59	1.00	0.50
TAC	3	4	0.89	1.00	0.76	0.51	0.96	0.04	0.72	0.99	0.33	0.63	1.00	0.56
TAC	3	6	0.92	1.00	0.80	0.54	0.98	0.05	0.75	1.00	0.36	0.66	1.00	0.61
TAC	3	7	0.80	1.00	0.89	0.57	0.99	0.09	0.68	1.00	0.49	0.64	1.00	0.75
TAC	3	10	0.87	1.00	0.93	0.63	1.00	0.16	0.76	1.00	0.63	0.72	1.00	0.86
TAC	3	12	0.93	1.00	0.93	0.67	0.99	0.22	0.83	1.00	0.66	0.78	1.00	0.87
TAC	3	13	0.84	1.00	0.95	0.66	0.99	0.42	0.75	1.00	0.77	0.74	1.00	0.91
TAC	3	15	0.90	1.00	0.96	0.73	0.99	0.52	0.82	1.00	0.83	0.81	1.00	0.94
TAE	1	1	0.87	1.00	0.68	0.49	0.92	0.07	0.69	0.97	0.33	0.59	1.00	0.50
TAE	1	4	0.88	1.00	0.69	0.49	0.92	0.07	0.69	0.97	0.33	0.60	1.00	0.50
TAE	1	6	0.88	1.00	0.69	0.50	0.93	0.07	0.70	0.97	0.34	0.60	1.00	0.51
TAE	1	7	0.88	1.00	0.85	0.62	0.96	0.25	0.76	0.98	0.58	0.70	1.00	0.73
TAE	1	10	0.91	1.00	0.86	0.66	0.96	0.29	0.80	0.98	0.62	0.73	1.00	0.76
TAE	1	12	0.91	1.00	0.86	0.66	0.97	0.29	0.80	0.98	0.62	0.74	1.00	0.77
TAE	1	13	0.92	1.00	0.95	0.73	0.99	0.50	0.84	1.00	0.79	0.80	1.00	0.90
TAE	1	15	0.95	1.00	0.95	0.77	0.99	0.53	0.87	0.99	0.81	0.83	1.00	0.90
TAE	1	16	0.87	1.00	0.91	0.65	0.98	0.31	0.77	0.99	0.69	0.72	1.00	0.83
TAE	1	17	0.92	1.00	0.93	0.70	0.99	0.40	0.83	1.00	0.74	0.78	1.00	0.87
TAE	1	18	0.93	1.00	0.94	0.73	0.99	0.42	0.85	1.00	0.77	0.80	1.00	0.90
			FPO			IPLL			IPPI			IPNI		
Output Control	HS	HCR	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75
TAC	1	1	0.89	1.00	0.79	0.53	0.98	0.05	0.73	0.99	0.36	0.65	1.00	0.60
TAC	1	4	0.92	1.00	0.82	0.56	0.98	0.05	0.77	1.00	0.40	0.68	1.00	0.65
TAC	1	6	0.93	1.00	0.82	0.57	0.98	0.06	0.78	1.00	0.41	0.69	1.00	0.65
TAC	1	7	0.85	1.00	0.91	0.62	0.99	0.20	0.74	1.00	0.61	0.70	1.00	0.80
TAC	1	10	0.92	1.00	0.93	0.68	0.99	0.28	0.82	1.00	0.68	0.77	1.00	0.85
TAC	1	12	0.95	1.00	0.94	0.72	0.99	0.32	0.86	1.00	0.72	0.82	1.00	0.88
TAC	1	13	0.87	1.00	0.97	0.69	1.00	0.49	0.78	1.00	0.82	0.77	1.00	0.94
TAC	1	15	0.92	1.00	0.97	0.76	1.00	0.57	0.85	1.00	0.85	0.84	1.00	0.95
TAC	3	1	0.84	1.00	0.72	0.48	0.96	0.02	0.66	0.99	0.26	0.59	1.00	0.50
TAC	3	4	0.89	1.00	0.76	0.51	0.96	0.04	0.72	0.99	0.33	0.63	1.00	0.56
TAC	3	6	0.92	1.00	0.80	0.54	0.98	0.05	0.75	1.00	0.36	0.66	1.00	0.61
TAC	3	7	0.80	1.00	0.89	0.57	0.99	0.09	0.68	1.00	0.49	0.64	1.00	0.75
TAC	3	10	0.87	1.00	0.93	0.63	1.00	0.16	0.76	1.00	0.63	0.72	1.00	0.86
TAC	3	12	0.93	1.00	0.93	0.67	0.99	0.22	0.83	1.00	0.66	0.78	1.00	0.87
TAC	3	13	0.84	1.00	0.95	0.66	0.99	0.42	0.75	1.00	0.77	0.74	1.00	0.91
TAC	3	15	0.90	1.00	0.96	0.73	0.99	0.52	0.82	1.00	0.83	0.81	1.00	0.94
TAE	1	1	0.87	1.00	0.68	0.49	0.92	0.07	0.69	0.97	0.33	0.59	1.00	0.50
TAE	1	4	0.88	1.00	0.69	0.49	0.92	0.07	0.69	0.97	0.33	0.60	1.00	0.50
TAE	1	6	0.88	1.00	0.69	0.50	0.93	0.07	0.70	0.97	0.34	0.60	1.00	0.51
TAE	1	7	0.88	1.00	0.85	0.62	0.96	0.25	0.76	0.98	0.58	0.70	1.00	0.73
TAE	1	10	0.91	1.00	0.86	0.66	0.96	0.29	0.80	0.98	0.62	0.73	1.00	0.76
TAE	1	12	0.91	1.00	0.86	0.66	0.97	0.29	0.80	0.98	0.62	0.74	1.00	0.77
TAE	1	13	0.92	1.00	0.95	0.73	0.99	0.50	0.84	1.00	0.79	0.80	1.00	0.90
TAE	1	15	0.95	1.00	0.95	0.77	0.99	0.53	0.87	0.99	0.81	0.83	1.00	0.90
TAE	1	16	0.87	1.00	0.91	0.65	0.98	0.31	0.77	0.99	0.69	0.72	1.00	0.83
TAE	1	17	0.92	1.00	0.93	0.70	0.99	0.40	0.83	1.00	0.74	0.78	1.00	0.87
TAE	1	18	0.93	1.00	0.94	0.73	0.99	0.42	0.85	1.00	0.77	0.80	1.00	0.90
TAE	3	1	0.85	1.00	0.85	0.53	0.90	0.14	0.69	0.95	0.42	0.62	1.00	0.57
TAE	3	4	0.88	1.00	0.88	0.49	0.94	0.04	0.69	0.98	0.30	0.59	1.00	0.50
TAE	3	6	0.88	1.00	0.88	0.48	0.94	0.04	0.68	0.98	0.29	0.58	1.00	0.48
TAE	3	7	0.85	1.00	0.85	0.60	0.97	0.19	0.73	0.99	0.56	0.67	1.00	0.72
TAE	3	10	0.91	1.00	0.91	0.65	0.97	0.28	0.80	0.99	0.62	0.73	1.00	0.76
TAE	3	12	0.92	1.00	0.92	0.67	0.97	0.29	0.81	0.99	0.64	0.74	1.00	0.77
TAE	3	13	0.90	1.00	0.90	0.70	0.99	0.44	0.81	1.00	0.77	0.78	1.00	0.89
TAE	3	15	0.94	1.00	0.94	0.75	0.99	0.49	0.86	1.00	0.79	0.82	1.00	0.90
TAE	3	16	0.84	1.00	0.84	0.62	0.99	0.21	0.74	1.00	0.67	0.69	1.00	0.84
TAE	3	17	0.92	1.00	0.92	0.71	1.00	0.37	0.83	1.00	0.80	0.78	1.00	0.92
TAE	3	18	0.95	1.00	0.95	0.74	1.00	0.41	0.88	1.00	0.81	0.82	1.00	0.93
TAE	2	1	0.94	1.00	0.95	0.72	0.99	0.37	0.86	1.00	0.76	0.80	1.00	0.90
			TWLL			KRLL			CHLL			VNLL		
Output Control	HS	HCR	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75	PM4	PM4 25	PM4 75
TAC	1	1	0.82	1.00	0.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	1	4	0.86	1.00	0.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	1	6	0.87	1.00	0.01	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	1	7	0.80	1.00	0.07	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	1	10	0.88	1.00	0.13	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	1	12	0.92	1.00	0.16	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	1	13	0.84	1.00	0.33	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	1	15	0.91	1.00	0.44	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	1	0.75	1.00	0.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	4	0.81	1.00	0.01	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	6	0.84	1.00	0.01	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	7	0.75	1.00	0.02	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	10	0.83	1.00	0.04	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	12	0.90	1.00	0.08	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	13	0.81	1.00	0.27	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAC	3	15	0.88	1.00	0.40	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	1	1	0.75	1.00	0.02	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.99
TAE	1	4	0.76	1.00	0.02	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.99
TAE	1	6	0.76	1.00	0.02	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.99
TAE	1	7	0.80	1.00	0.13	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.99
TAE	1	10	0.84	1.00	0.17	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.99
TAE	1	12	0.84	1.00	0.18	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	1	13	0.88	1.00	0.38	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	1	15	0.90	1.00	0.43	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	1	16	0.81	1.00	0.17	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	1	17	0.86	1.00	0.25	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	1	18	0.88	1.00	0.28	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	1	0.75	1.00	0.08	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.98
TAE	3	4	0.76	1.00	0.01	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	6	0.76	1.00	0.01	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	7	0.78	1.00	0.09	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	10	0.83	1.00	0.17	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	12	0.85	1.00	0.18	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	13	0.85	1.00	0.32	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	15	0.89	1.00	0.38	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	16	0.79	1.00	0.07	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	17	0.87	1.00	0.19	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	3	18	0.90	1.00	0.24	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
TAE	2	1	0.89	1.00	0.22	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00

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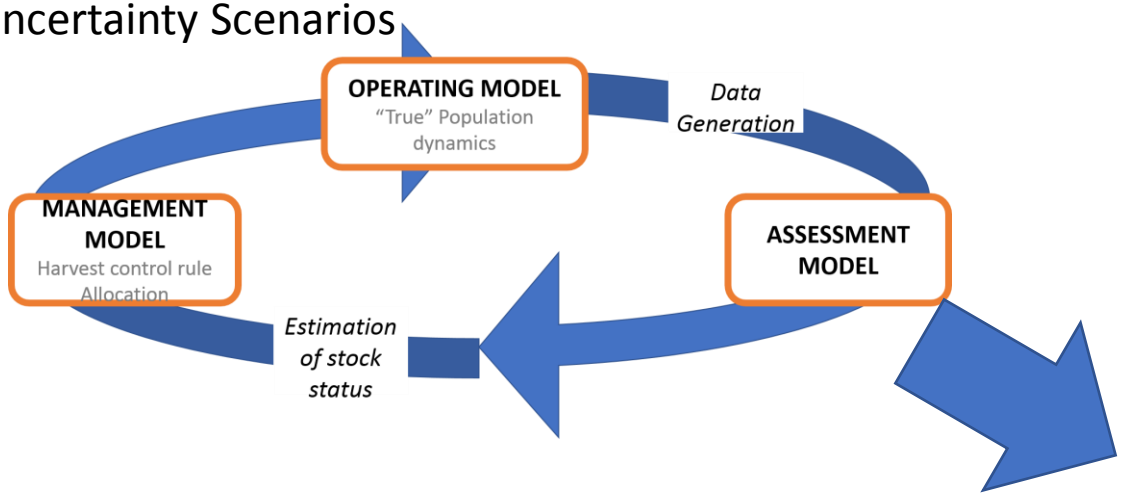

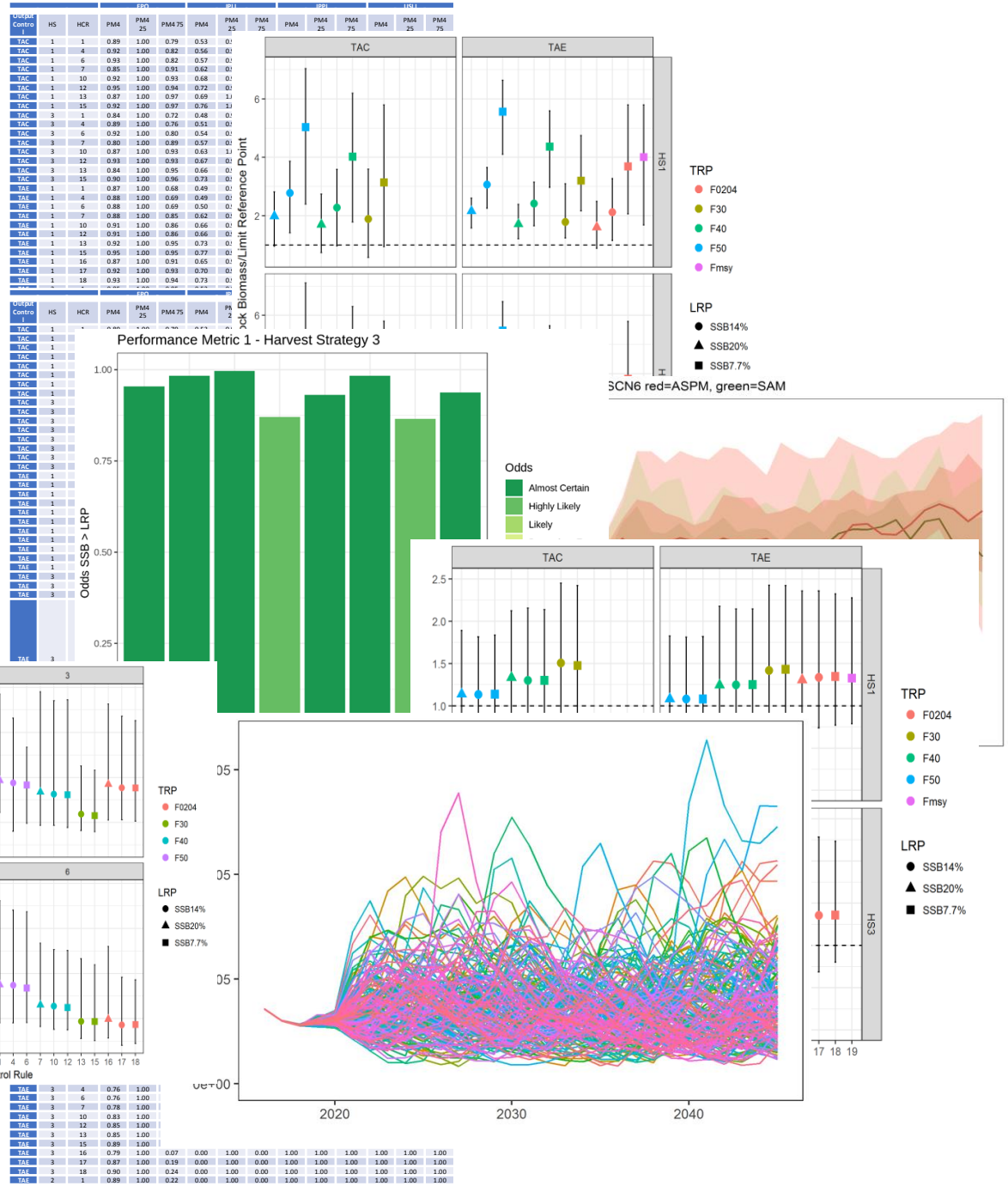

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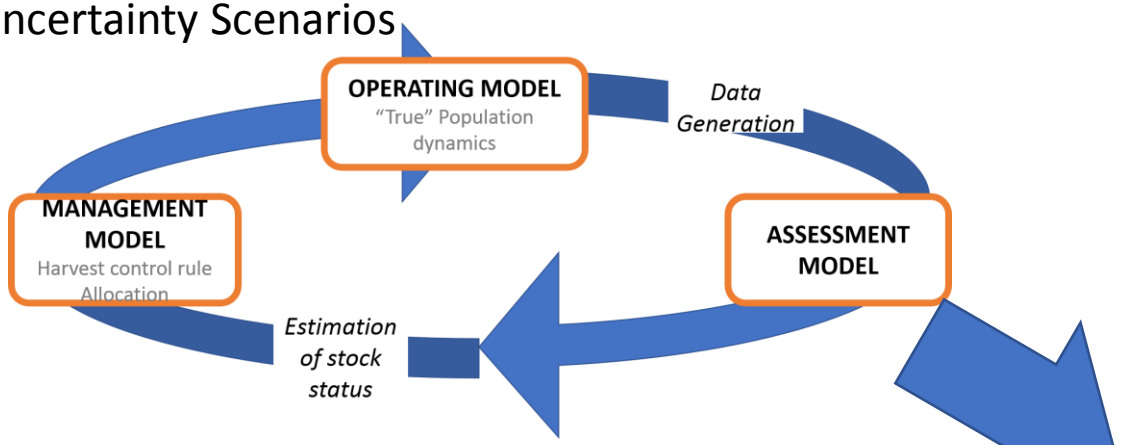
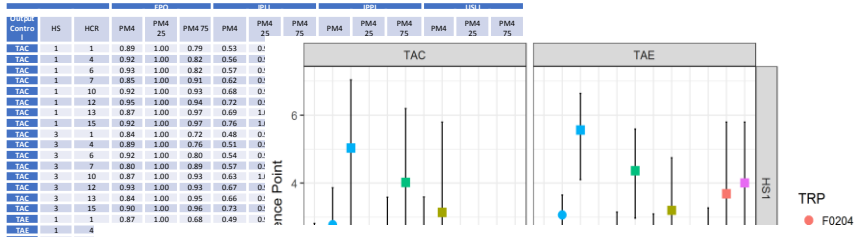
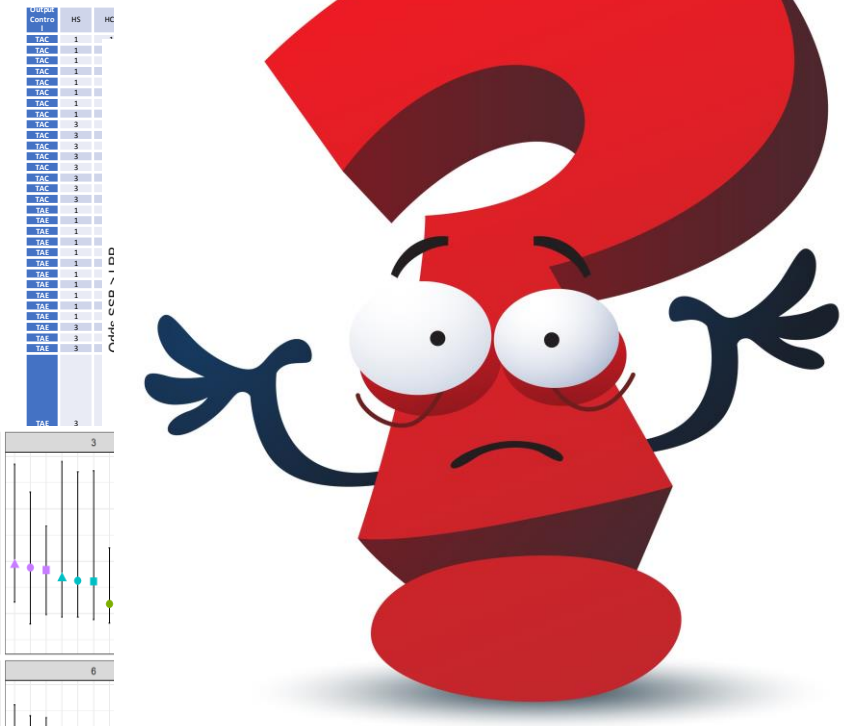
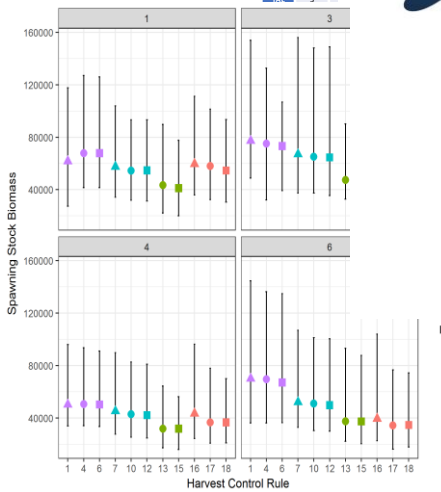
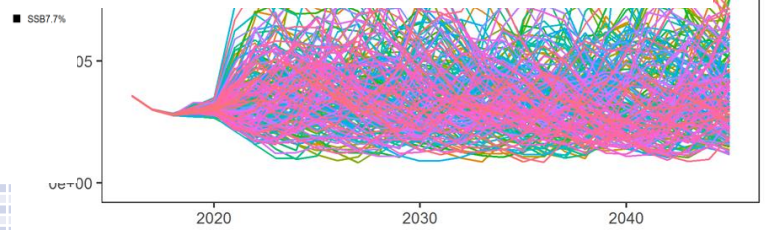
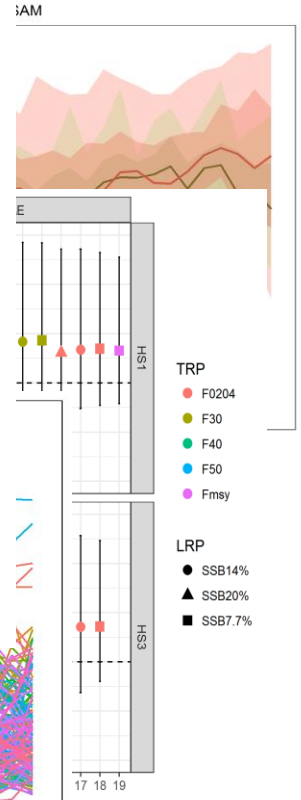






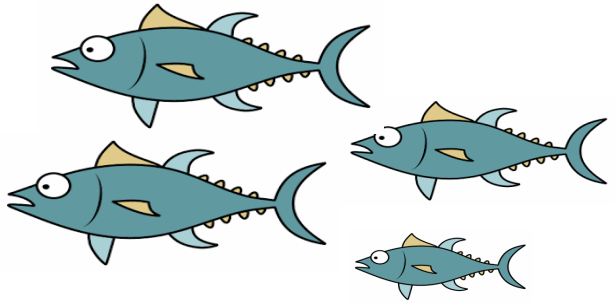




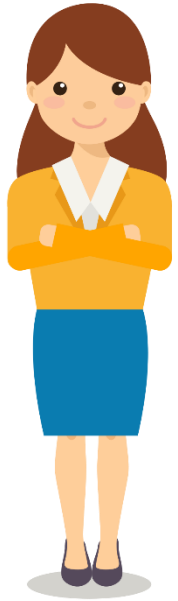


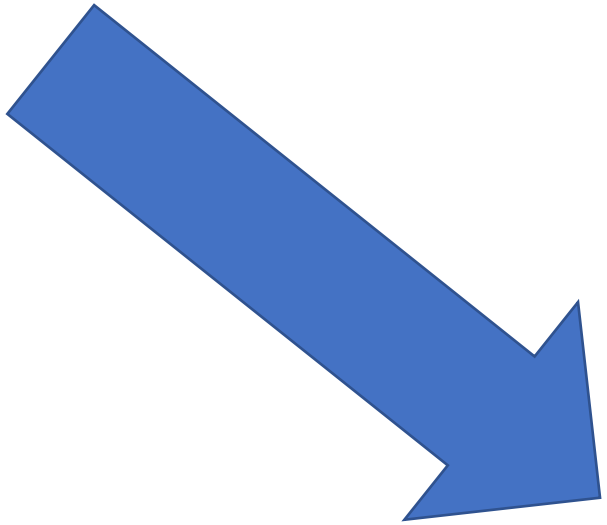
Management Objectives

- High level goals of a management plan
  - E.g. Prevent overfishing, Promote profitability of the fishery
- Agreed upon by managers and stakeholder
- Key to assess performance of harvest strategies
- Often conflicting
- Not quantitative



Management Objectives

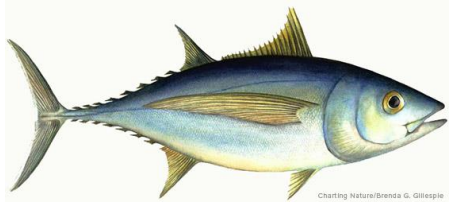




Performance Metrics

Quantitative indicators that are used to evaluate HCRs

MSE Case Study – North Pacific Albacore



Goal: Evaluate candidate target reference points and associated harvest strategies and control rules

Which harvest strategy do I set that will let me achieve the management goals? Lots of choices…

Use MSE to compare them!

International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

CIAT IATTC

Western and Central Pacific Fisheries Commission

Timeline for North Pacific Albacore MSE

1st ISC MSE WS (16-17 April 2015 at Yokohama, JAPAN)

- **71 participants:** fishery managers, stakeholders, NGOs, and scientists
- **Purpose:** to learn about and understand the MSE process; review the objectives, benefits, and requirements to implement an MSE; as well as recent progress made by tuna RFMOs towards adopting and implementing the MSE process

2nd ISC MSE WS (24-25 May 2016 at Yokohama, JAPAN)

- **24 participants:** fishery managers, stakeholders, NGOs, and scientists
- **Purpose:** to develop management objectives and performance indicators, based on input from managers, stakeholders and scientists

3rd ISC MSE WS (17-19 October 2017 at Vancouver, CANADA)

- **23 participants:** fishery managers, stakeholders, NGOs, and scientists
- **Purpose:** to identify acceptable level of risk for each management objective; and develop candidate reference points and harvest control rules for testing

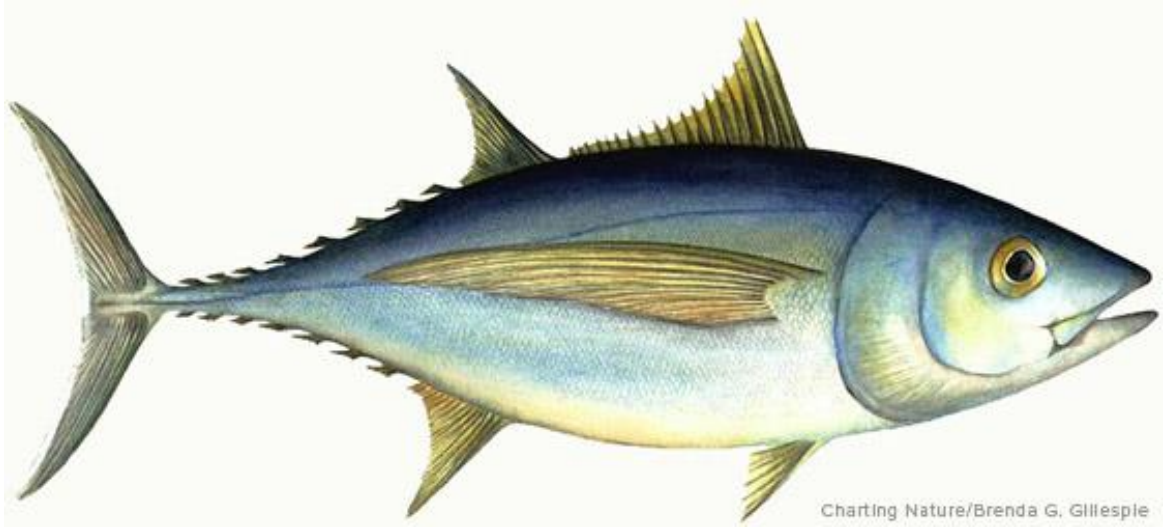
Timeline for North Pacific Albacore MSE

4th ISC MSE WS (5-7 March 2019 at Yokohama, JAPAN)

- **25 participants:** fishery managers, stakeholders, NGOs, and scientists
- **Purpose:** to discuss results of first round of MSE and make recommendations

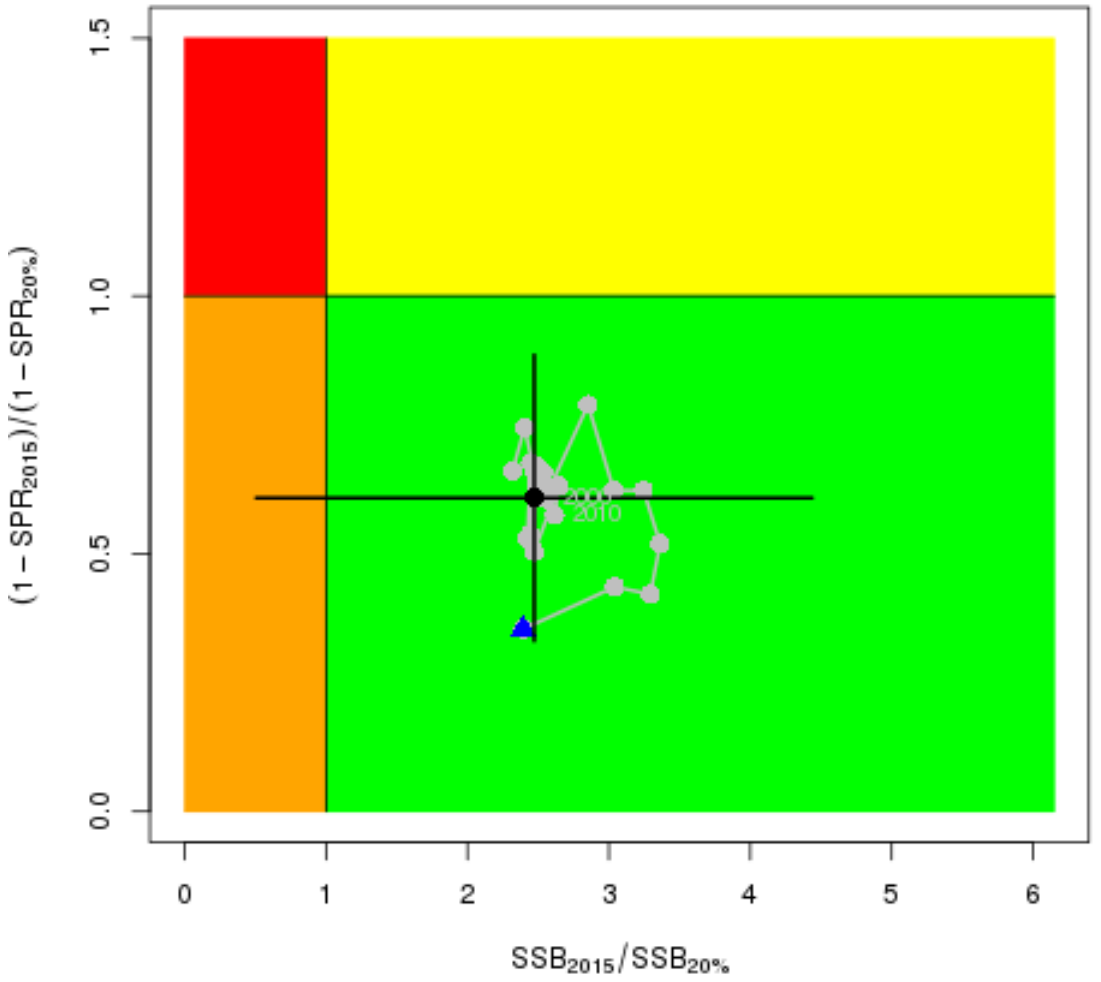
5th ISC MSE WS (TBD)

- **Purpose:** to discuss results of second round of MSE and make recommendations

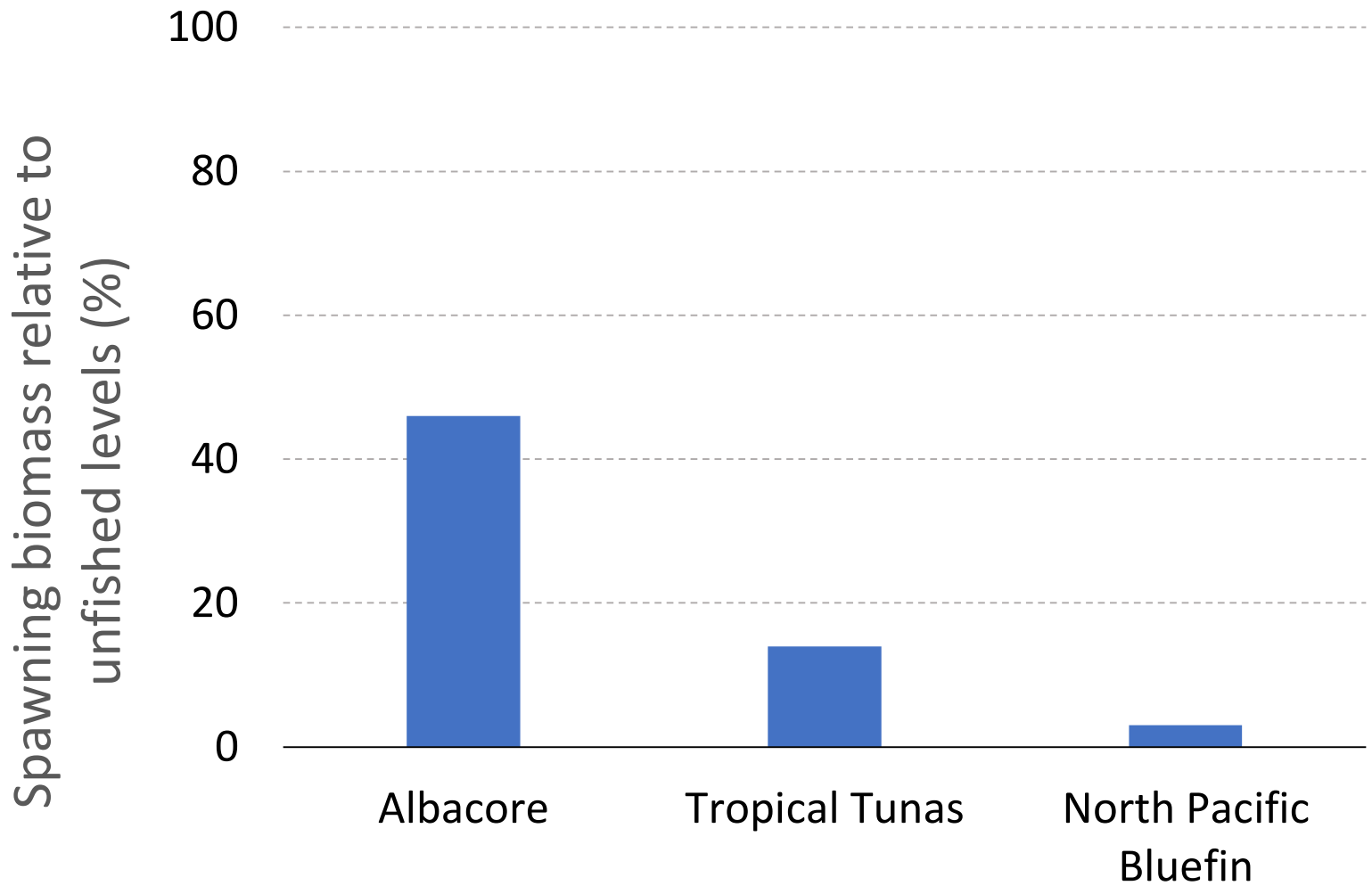


Current Stock Status of North Pacific Albacore

- Last assessment was in 2017
- Not in overfished condition $SSB_{2015}/0.2SSB_{0,F=0} > 1$
- 2015 female SSB at about 47% of unfished female SSB
- Not experiencing overfishing $F_{2012\text{-}2014}/F_{20\%} < 1$
- $F_{2012\text{-}2014}$ at about $F_{50\%}$

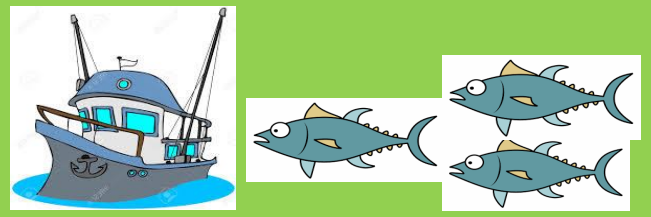


North Pacific Albacore Stock Status



Management Objectives

MANAGEMENT OBJECTIVES



1. Have infrequent management intervention
2. Maintain biomass
3. Maintain equitable share of catch among different fisheries
4. Maintain catch
5. Have stability in catch
6. Fish at the target level set by management

MANAGEMENT OBJECTIVES
1. Maintain SSB above the limit reference point (LRP)
2. Maintain depletion of total biomass around historical average depletion
3. Maintain harvest ratios by fishery at historical (2006-2010) average
4. Maintain catches above average historical catch
5. Change in total allowable catch between years should be relatively gradual
6. Maintain fishing intensity (F) at the target value with reasonable variability

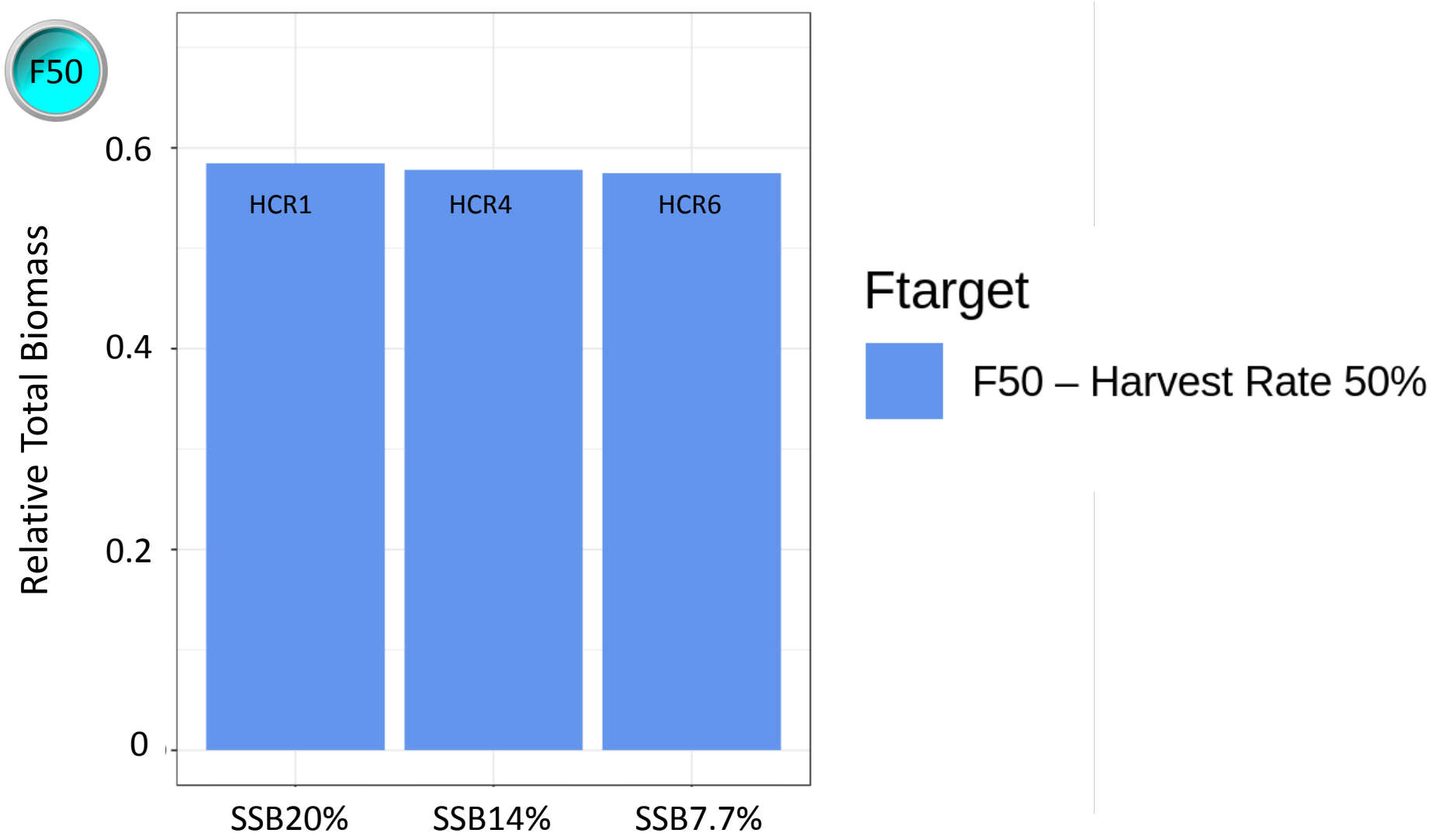
Management Objectives and Performance Metrics

Management Objective	Label	Performance Metrics
1. Maintain SSB above the limit reference point (LRP)	Odds of no fishery closure	Probability that SSB in any given year of the MSE forward simulation is above the LRP
2. Maintain depletion of total biomass around historical average depletion	Relative Total Biomass	Probability that depletion in any given year of the MSE forward simulation is above minimum historical (2006-2015) depletion
4. Maintain catches above average historical catch	Relative Total Catch	Probability that catch in any given year of the MSE forward simulation is above average historical (1981-2010) catch
5. Change in total allowable catch between years should be relatively gradual	Catch Stability	Probability that a decrease in TAC between years is < 30%. Calculated excluding years TAC=0.
6. Maintain fishing intensity (F) at the target value with reasonable variability	F_{TARGET}/F	F_{TARGET}/F

Compared Performance of Many Harvest Control Rules

Harvest strategy	Output control	Harvest control rule	Ftgt	SSBthr	SSBlim
1 or 3	TAC or TAE	1	F50	30%SSB	20%SSB
1 or 3	TAC or TAE	4	F50	20%SSB	14%SSB
1 or 3	TAC or TAE	6	F50	14%SSB	7.7%SSB
1 or 3	TAC or TAE	7	F40	30%SSB	20%SSB
1 or 3	TAC or TAE	10	F40	20%SSB	14%SSB
1 or 3	TAC or TAE	12	F40	14%SSB	7.7%SSB
1 or 3	TAC or TAE	13	F30	20%SSB	14%SSB
1 or 3	TAC or TAE	15	F30	14%SSB	7.7%SSB
1 or 3	TAE	16	F0204	30%SSB	20%SSB
1 or 3	TAE	17	F0204	20%SSB	14%SSB
1 or 3	TAE	18	F0204	14%SSB	7.7%SSB

A lower fishing intensity TRP results in higher biomass



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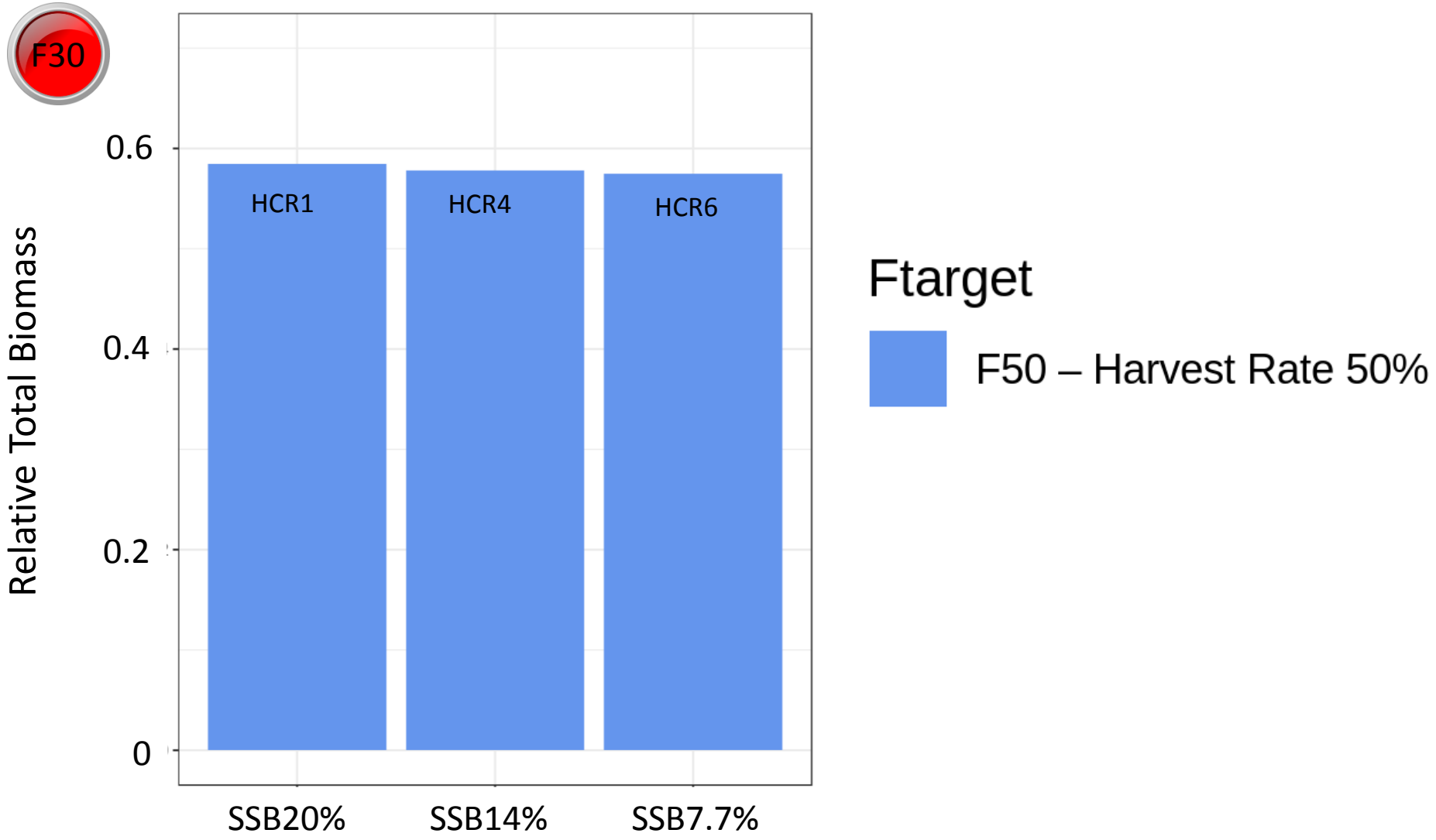

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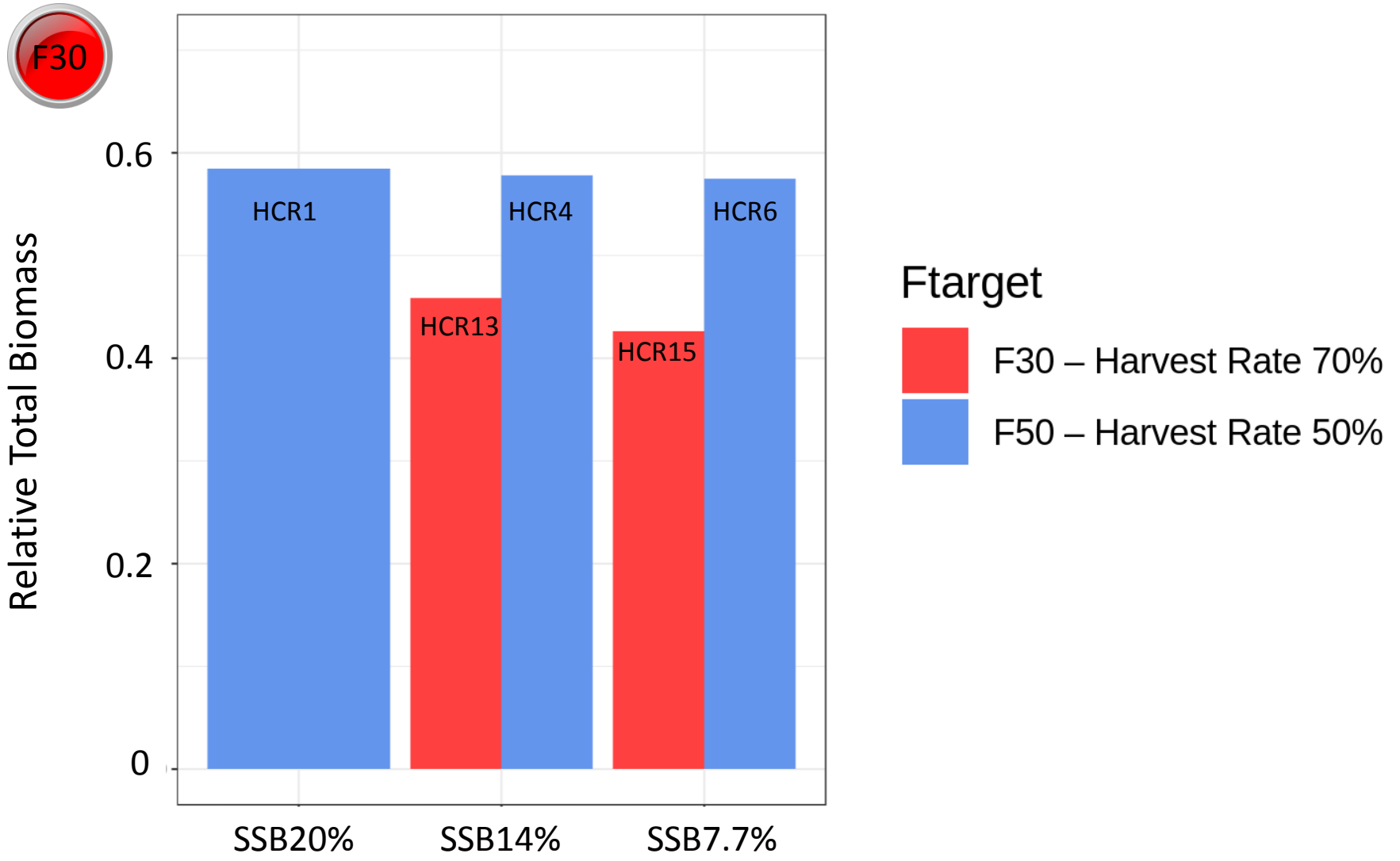

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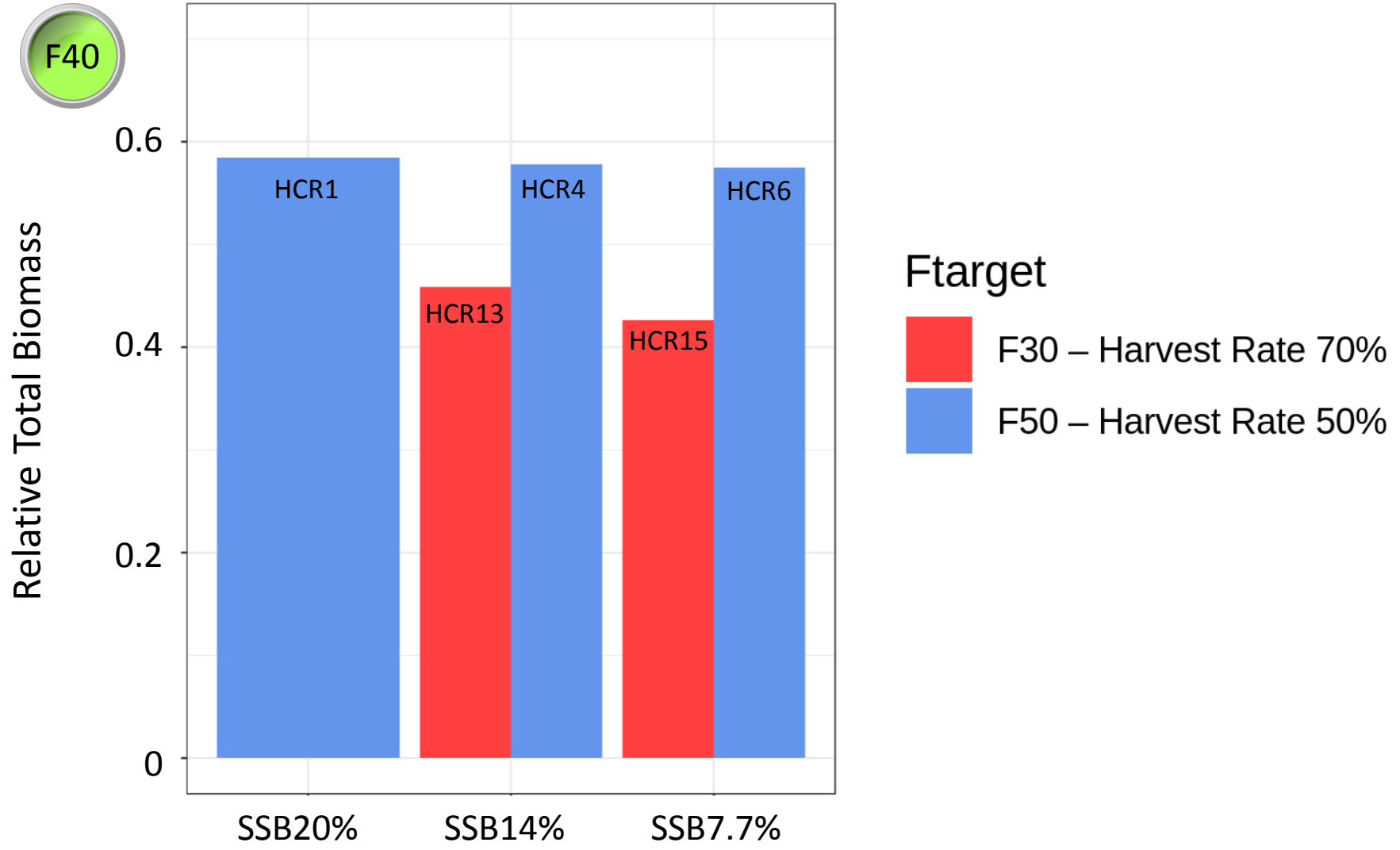

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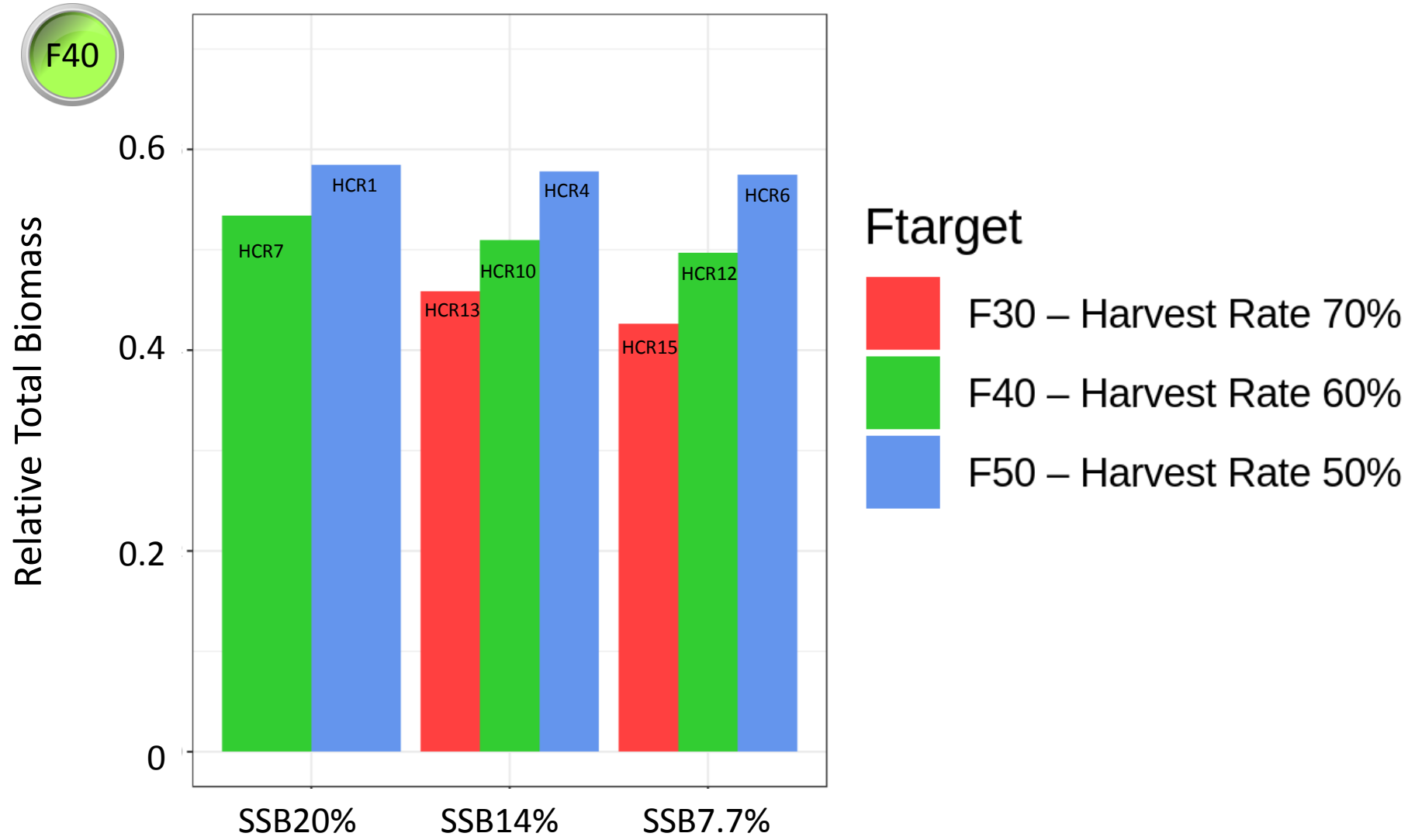
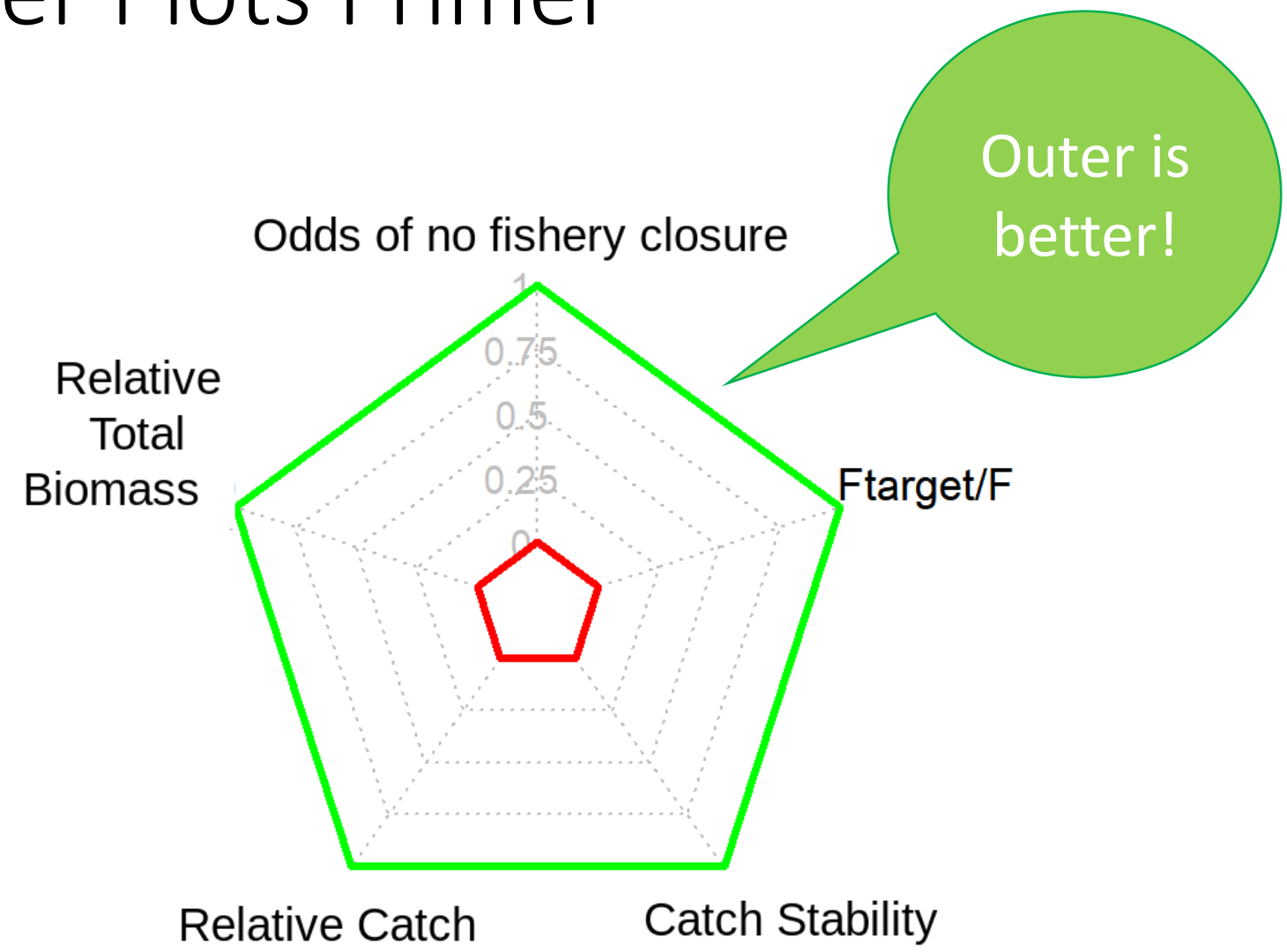
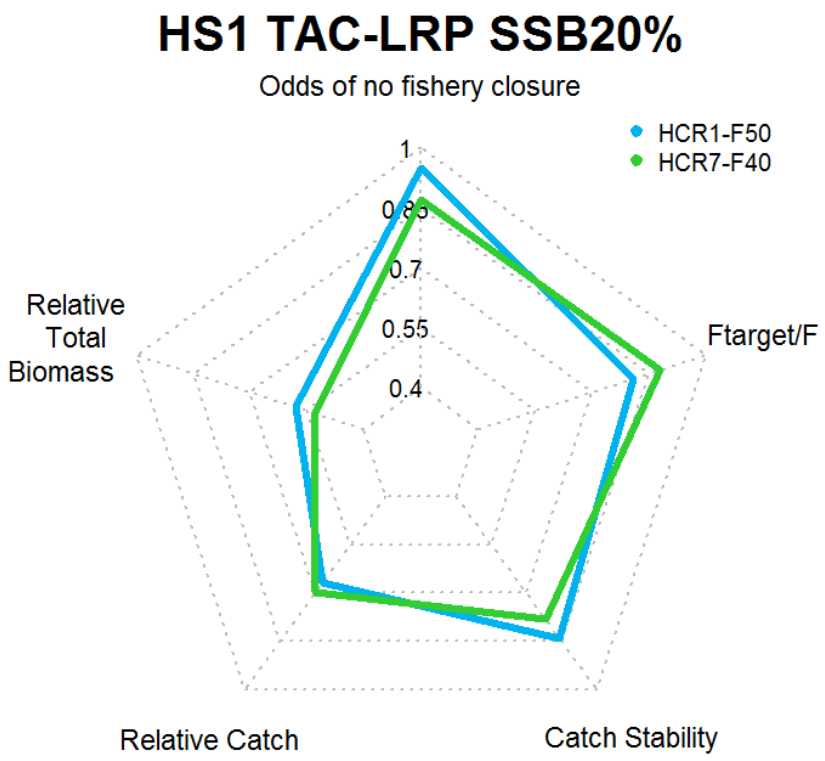
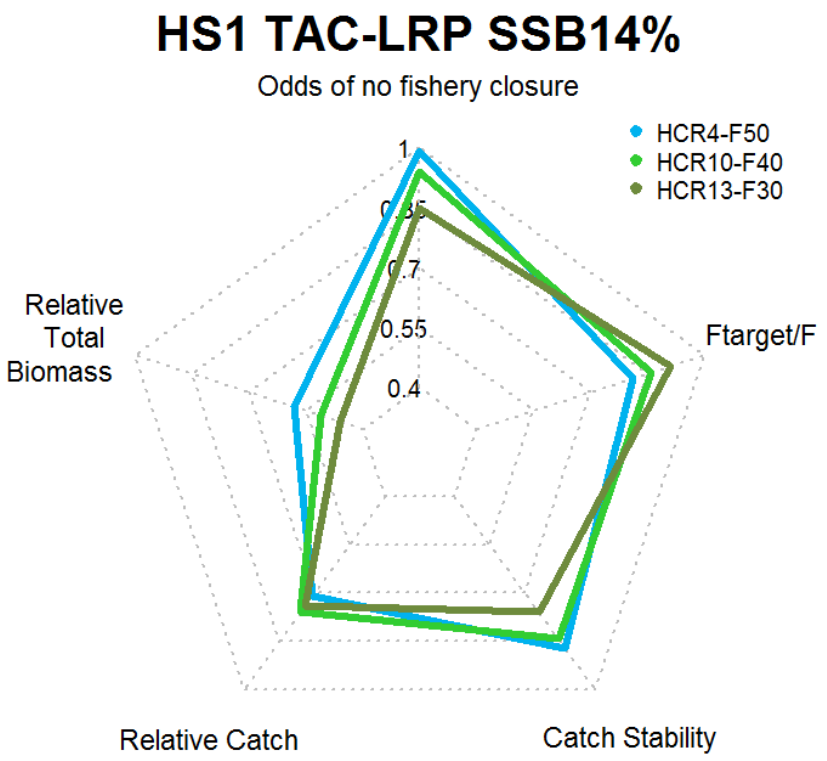


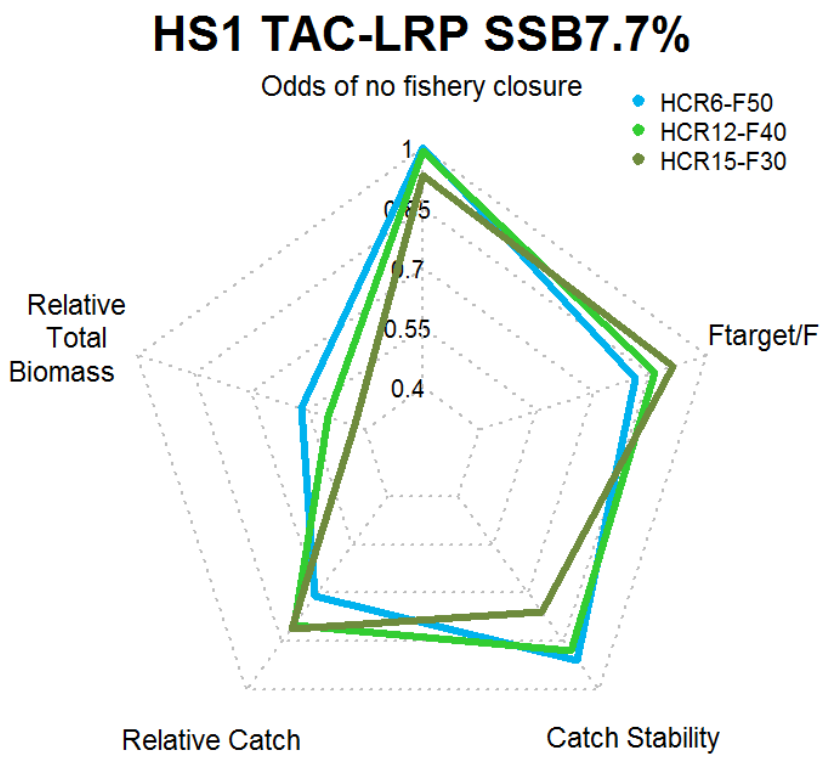
Spider Plots Primer



Trade-offs among performance metrics







Conclusions

1. A lower fishing intensity TRP (i.e. F50), maintains the population at a higher level than F40 and F30, requiring less management intervention and resulting in lower catch variability between years. However, lower fishing intensity results in lower overall catch.
2. HCRs with a TRP of F40 have less closures and higher catch stability as compared to a TRP of F30, resulting in comparable or higher catch despite lower fishing intensity.
3. An LRP and threshold reference point closer to the TRP results in a higher frequency of management interventions, fishery closures and lower catch stability.
4. HS3 showed lower catch stability than HS1, but had less fishery closures.
5. Harvest strategies with Total Allowable Effort (TAE) control performed better than ones with Total Allowable Catch (TAC) control across all performance metrics.

Outcome of first round of North Pacific Albacore MSE

- No management recommendations for WCPFC and IATTC
- Results from 2nd round of MSE to be presented at 5th MSE Workshop in late 2020 – early 2021
- Smaller, more focused list of RPs and HCRs
- Stricter risk level (80 or 90%) used to evaluate risk of breaching candidate LRPs
- Evaluate 2 candidate levels of control if LRP breached
- Evaluate option where fleets not under control if SSB ≥ $SSB_{THRESHOLD}$
- Use historical (1997 – 2015) fishing intensity or mortality levels to represent available fishing effort

MSE Example - Pacific sardine

Management Objectives

1. Promote efficiency and profitability in the fishery, including stability of catch
2. Achieve optimum yield
3. Provide adequate forage for dependent species
4. Prevent overfishing

MSE Example - Pacific sardine

Performance Metrics

1. Mean and Standard Deviation of Age 1+ Biomass
2. Mean and Standard Deviation of Spawning Stock Biomass
3. % Biomass Age 1+ > 400,000 mt
4. Depletion (biomass in fished state/biomass in unfished)
5. Mean and Standard Deviation of Catch
6. % Catch < 50,000 mt
7. % No Catch

MSE Example - Pacific sardine

Strategies/HCRs

HG = (BIOMASS – CUTOFF)*FRACTION*DISTRIBUTION

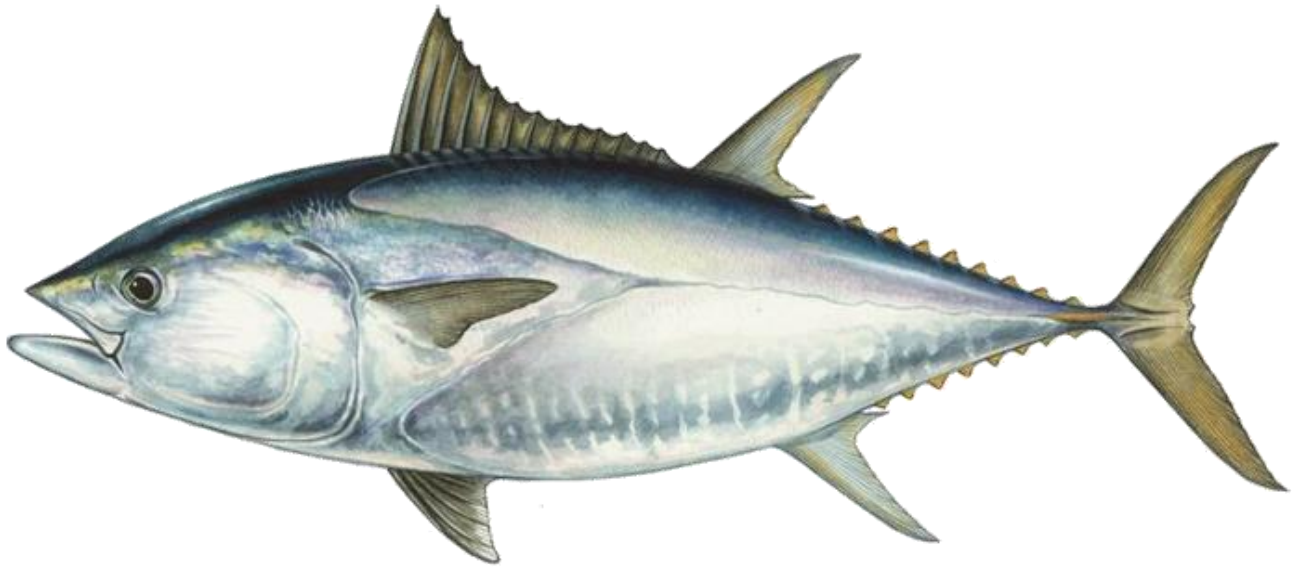
- FRACTION depends on CalCOFI SST
- Different CUTOFF values
- Different bounds on FRACTION

MSE process was about 2 years long and led to the use of CalCOFI SST in Current harvest guideline

MSE Example – Southern Bluefin tuna

Background: high uncertainty in stock assessment results, for almost a decade managers struggled to reach agreement on TAC

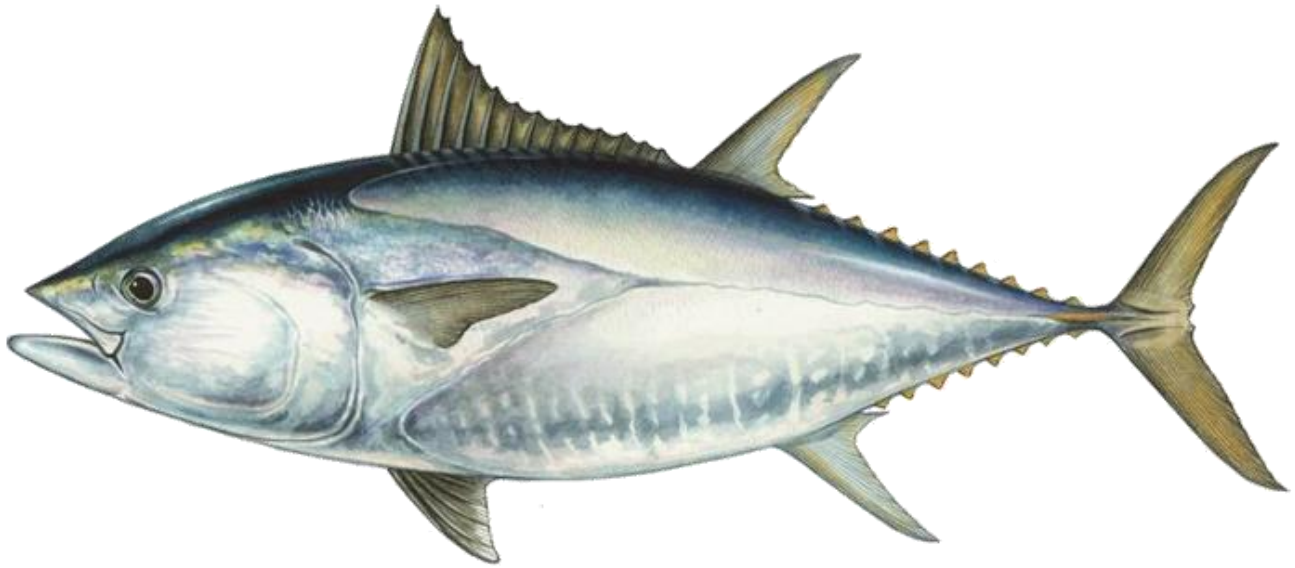
Goal: To evaluate the performance of pre-agreed upon management procedures



MSE Example – Southern Bluefin tuna

Management Objectives

1. Maximize catches
2. Avoid stock collapse
3. Minimize interannual catch variation

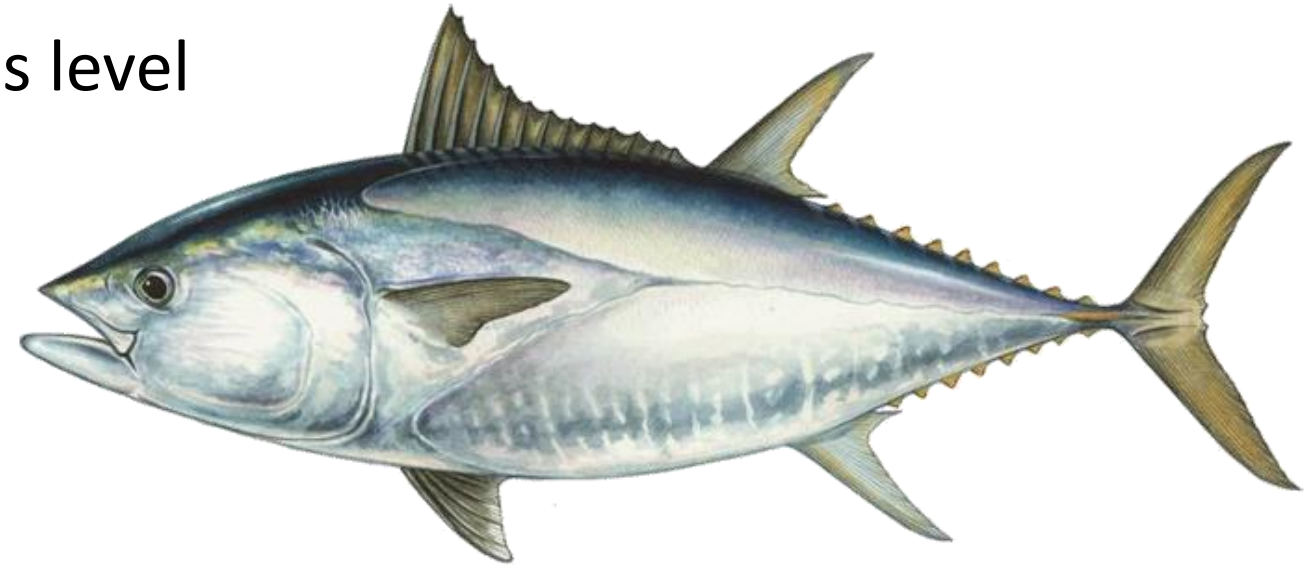


Kurota et al. 2010

MSE Example – Southern Bluefin tuna

Performance Metrics

1. Short and Long term mean catch
2. Catch variability
4. Maximum TAC decrease between years
5. Mean biomass
6. Risk of falling below low biomass level



Kurota et al. 2010

MSE Example – Southern Bluefin tuna

Development of MSE framework took longer than 10 years!

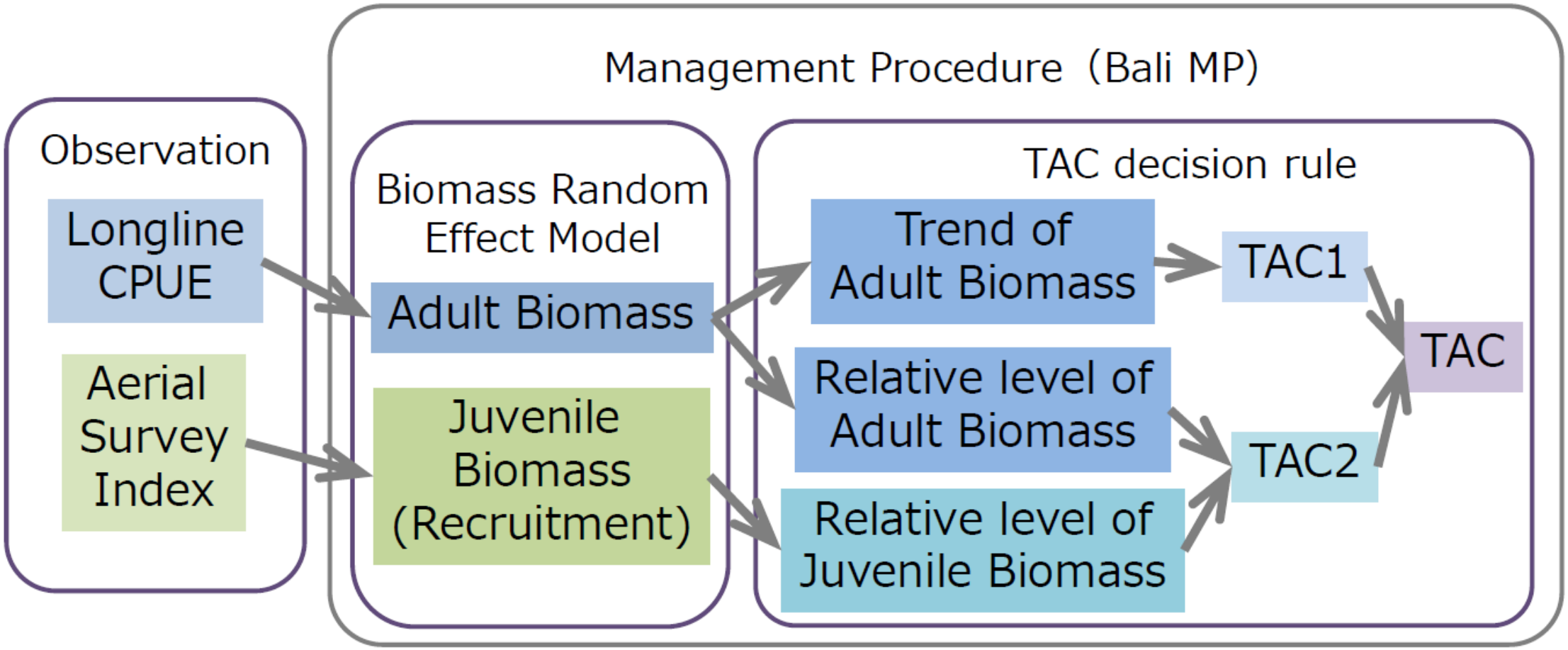


Figure from http://isc.fra.go.jp/pdf/2015_MSE/4-1c_Sakai_ISC_MSE_2015-0417.pdf

Lesson Learned

- MSE is an iterative process
- Having set of pre-agreed management objectives at the start essential
- Start small (in terms of HCRs, reference points, scenarios to test)
- Ideal set of HCRs and scenarios may have to be refocused given reality of available resources
- Engagement of managers, stakeholders, and scientists important to produce relevant and useful results

Lesson Learned

- MSE output can be overwhelming

-Scientists: take time to explain things many times in different ways

-Managers/Stakeholders: it may take scientists a few tries to figure out how to best convey results…don't give up ☺

- Feedback from managers and stakeholders important to improve communication strategy
- When interpreting results be aware of limitations of MSE framework

Thank you!