INTERNATIONAL PACIFIC HALIBUT COMMISSION

Ensemble models and characterizing risk in stock assessments

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Applied Stock Assessment class

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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)

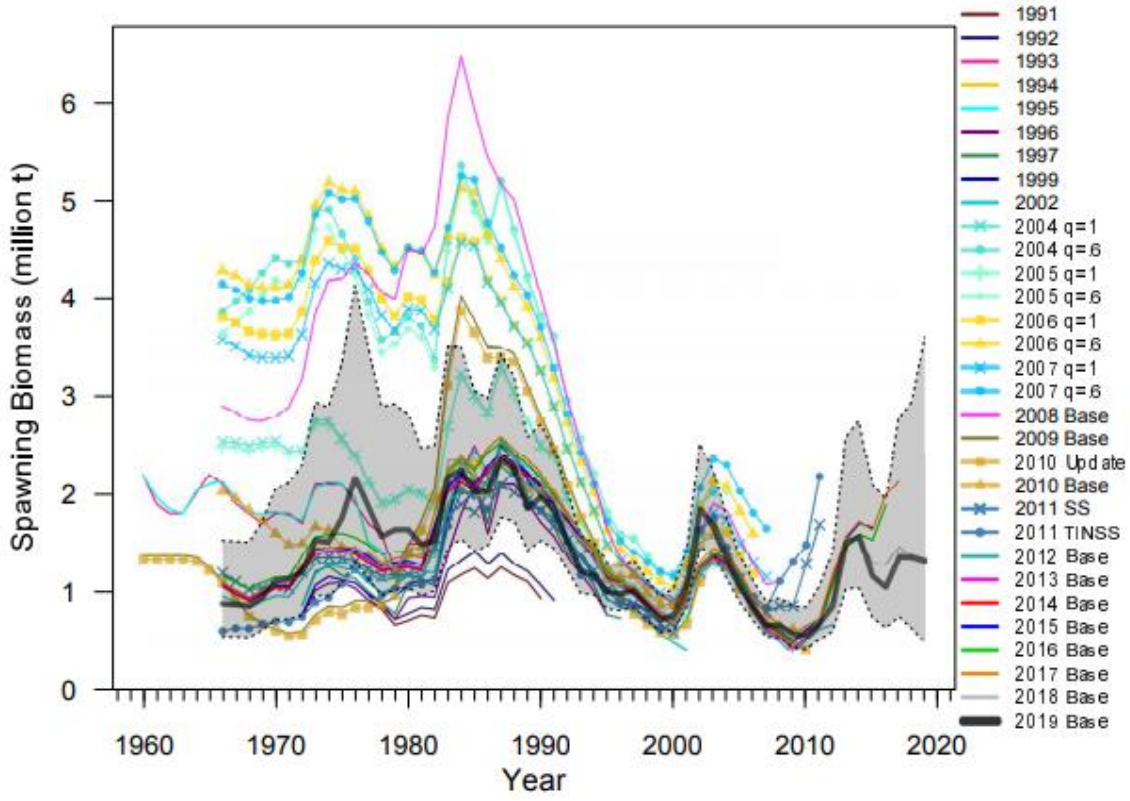
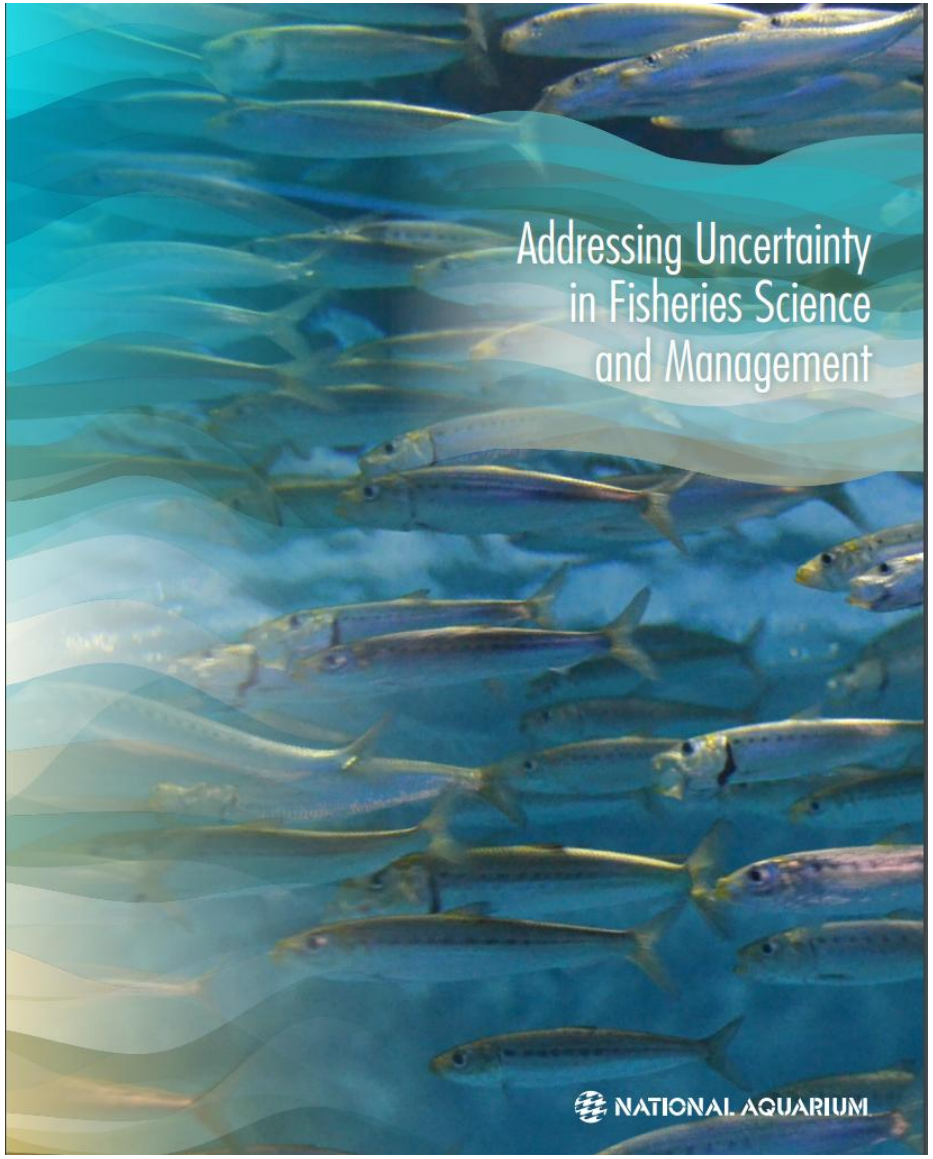


Figure 71. Summary of historical Pacific Hake assessment estimates of spawning biomass. Estimates are MLEs or MCMC medians depending on the model structure. Shading represents the approximate 95% confidence range from the 2019 base model.

Four types of uncertainty

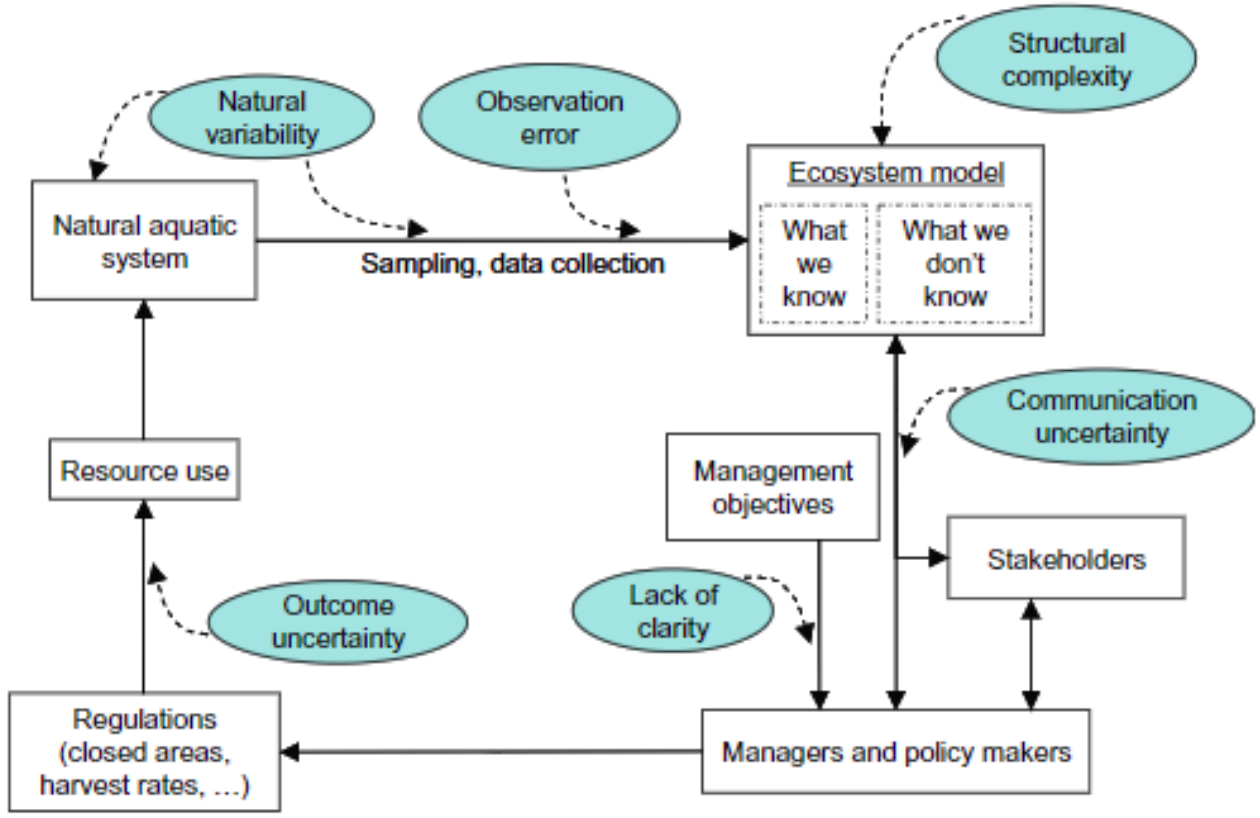
1. Data Uncertainty
   - A result of variability in collection of data
   - Amount and types of data available
2. Model & Assessment Uncertainty
   - Modelling methods, assumptions, parameterizations
3. Ecosystem or Population Uncertainty
   - Unknown ecosystem relationships
   - Natural variability in the ecosystem
4. Outcome & Implementation Uncertainty
   - Setting the right target or limit
   - Accuracy of meeting the established target



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

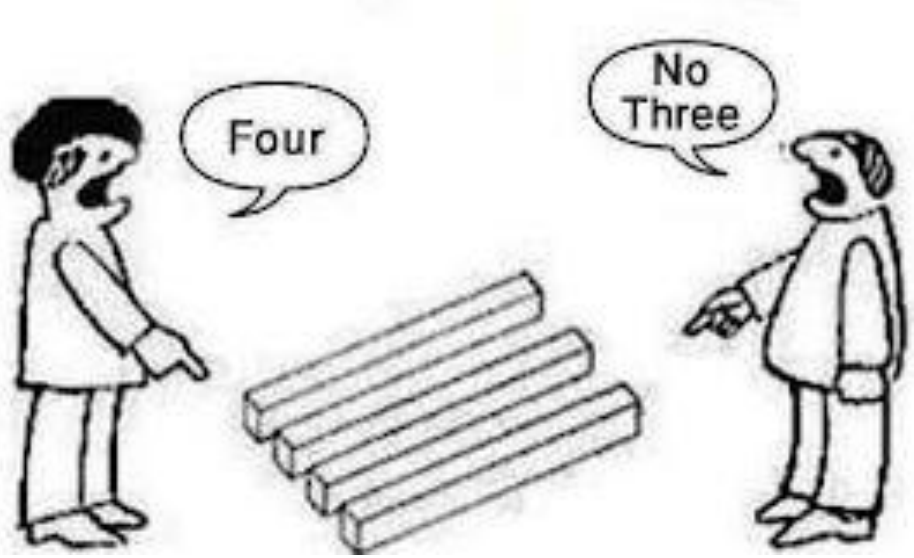


Link et al 2012. Prog. Oceanogr.

Another type of uncertainty

Perception uncertainty

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



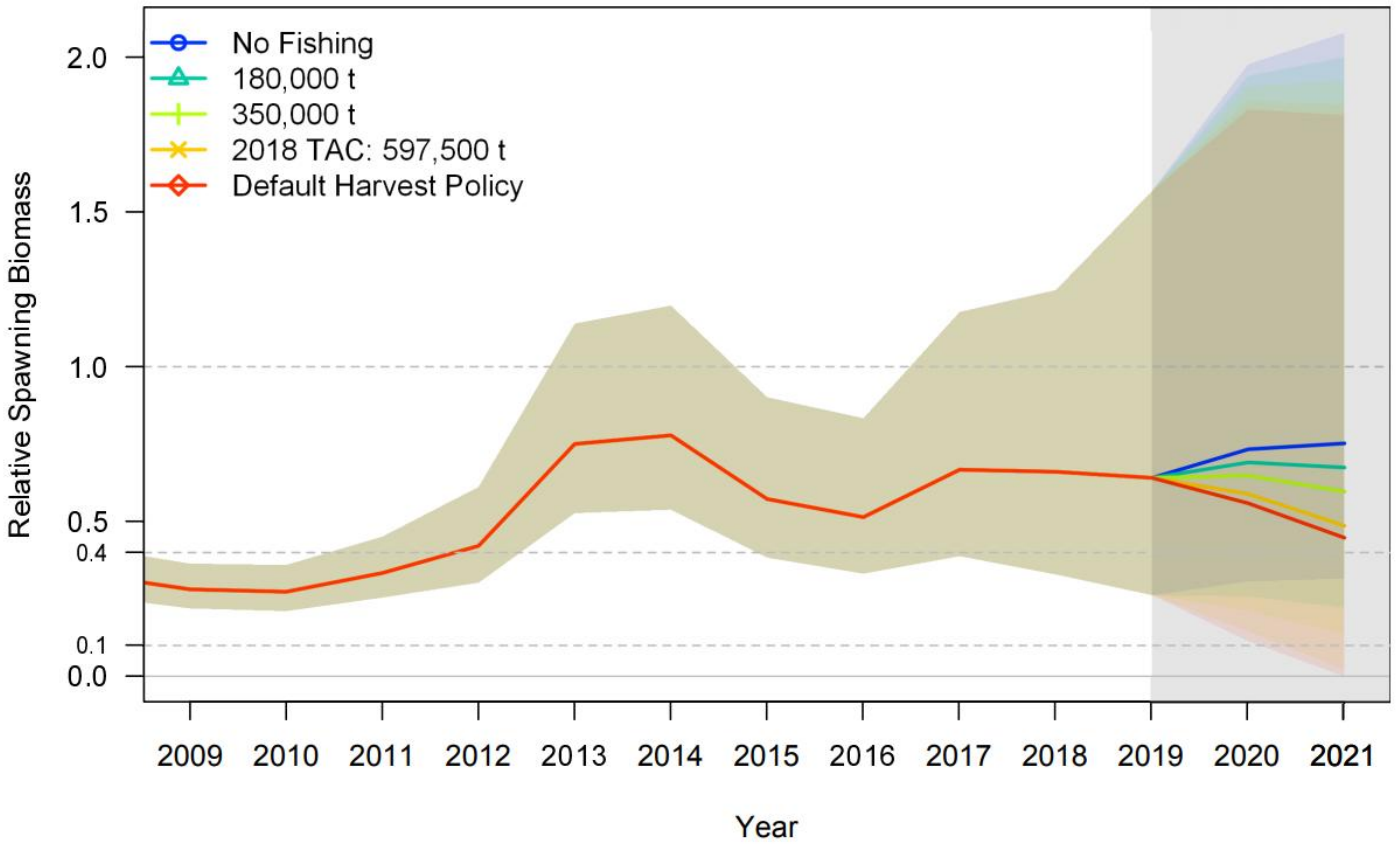
www.debate.org

Tactical Decision-making

Short-term forecast (stock assessment)

- Prediction models with uncertainty
- Forecast only as far as the data allow

2019 Hake Assessment (Berger et al)



Is there a perfect assessment model?

- Is unbiased/No retrospective bias
- Performs well regardless of stock trend
- Adapts to changes in the fishery
- Accounts for changes in the life-history
- Able to forecast reasonably well
- Quantifies uncertainty

www.History.com

- IPHC was chasing the perfect halibut model for four decades

A single assessment model typically can not capture all of these

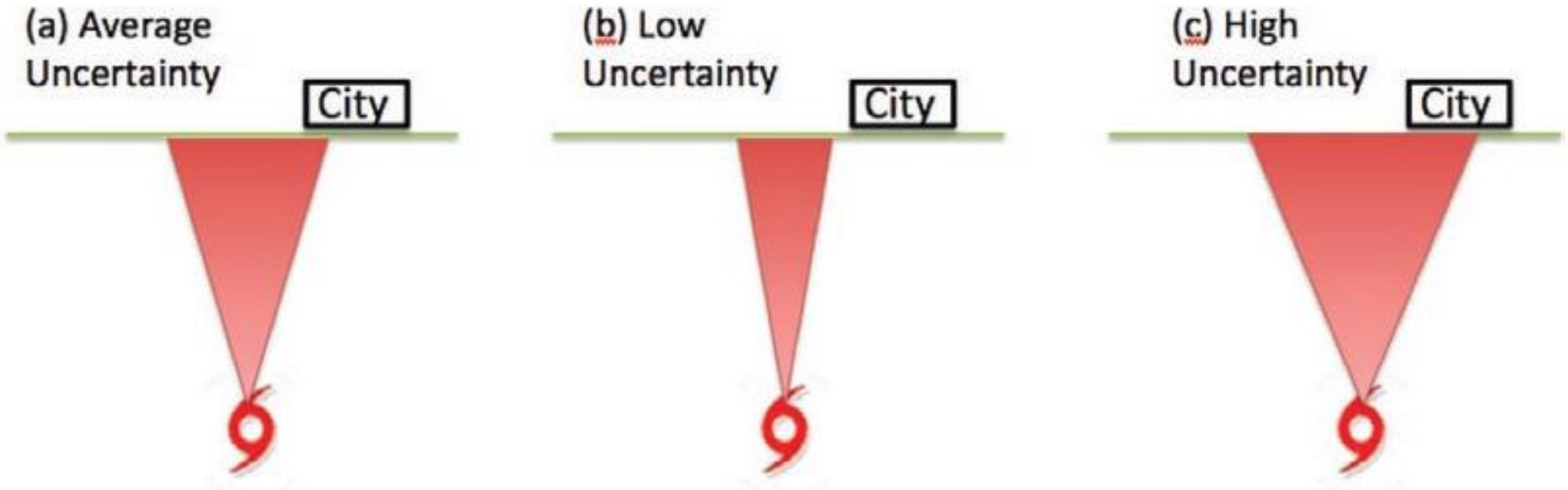
Admitting we don’t have a perfect model

The fleet already knew that.

IPHC transitioned to an ensemble in 2013

- A move from “catch advice” to risk analysis
  - Better quantification of uncertainty
  - Clear separation of science and management

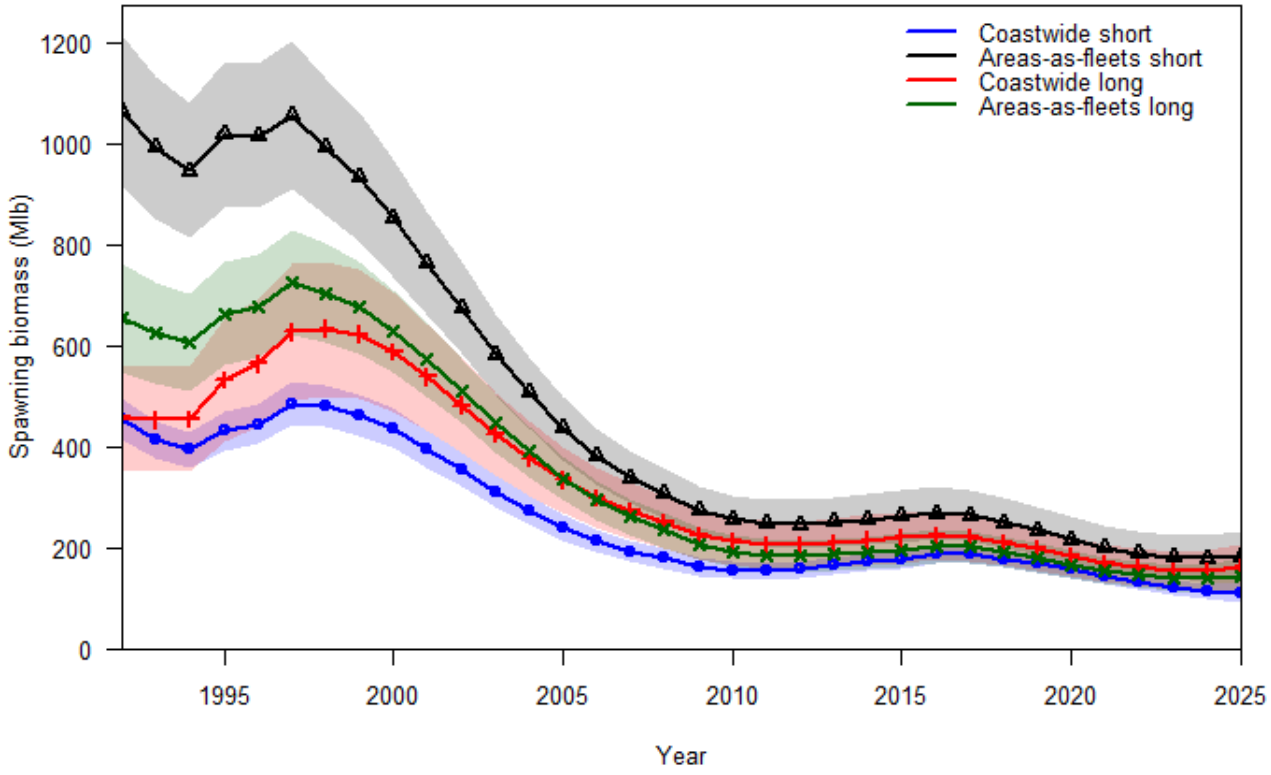
(Good) Decision making depends on uncertainty



Hamill, T. M., M. J. Brennan, B. Brown, M. DeMaria, E. N. Rappaport and Z. Toth (2012). "NOAA's Future Ensemble-Based Hurricance Forecast Products." Bulletin of the American Meteorological Society 93: 209-220.

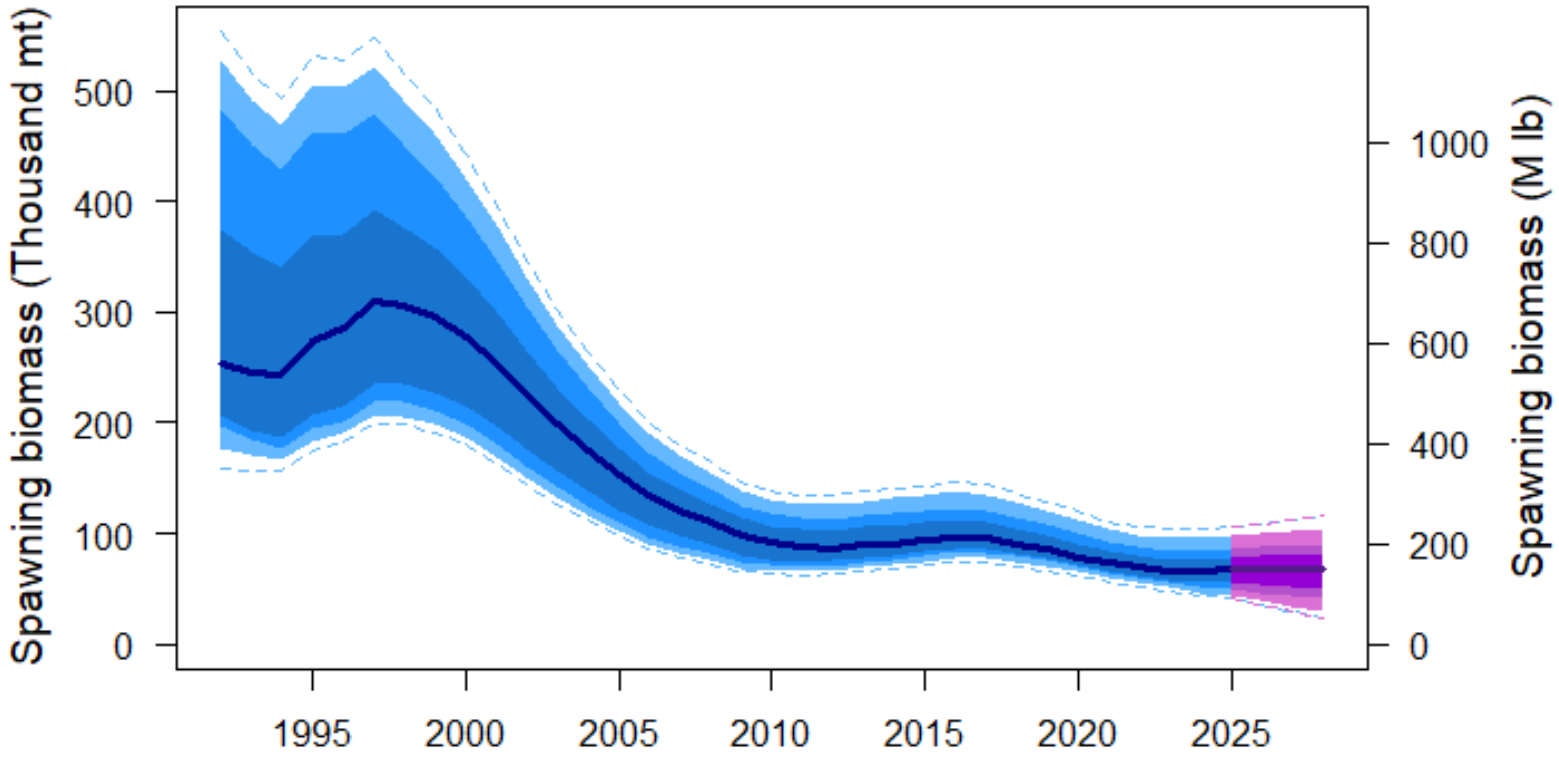
Ensemble model

- A pragmatic four model ensemble
  - Short and Long time-series
  - Coastwide or areas-as-fleets
- Each has been evaluated and has pros and cons
- Uncertainty is structural and not easily adapted to statistical model averaging
- Retains the within-model uncertainty
  - This is not the average of the point estimates



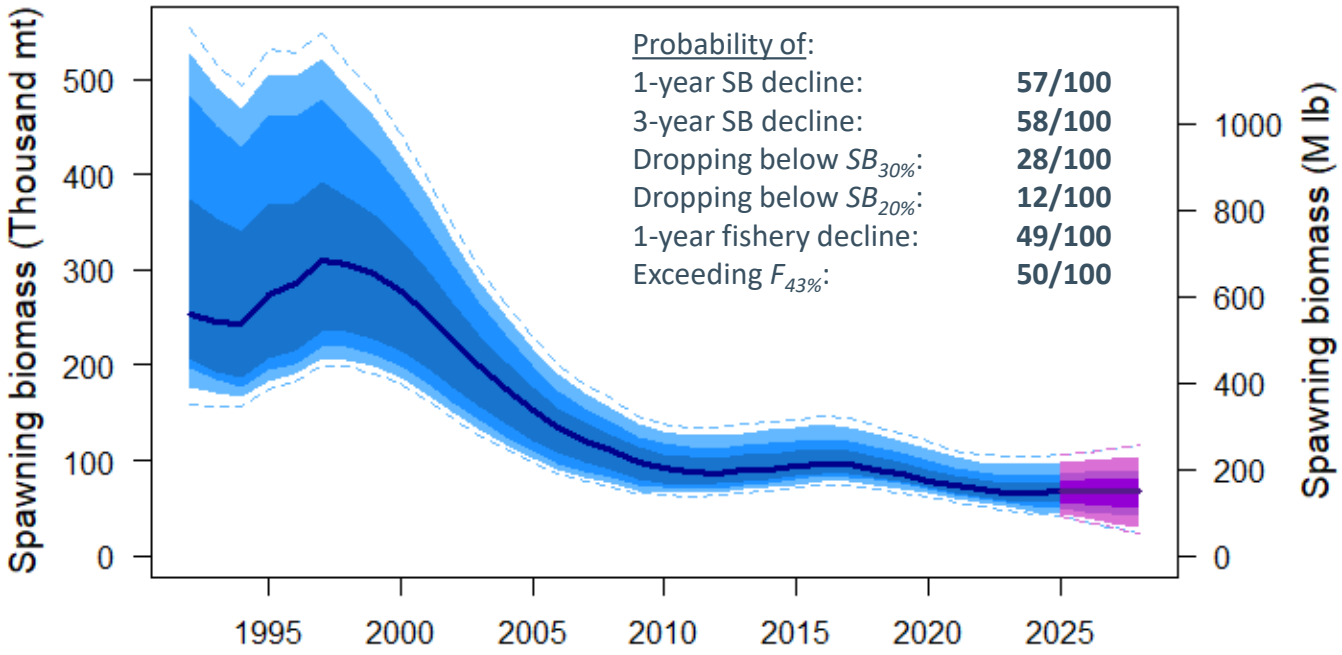
Stock assessment at IPHC

- Integrated Estimates
  - Output from each model is equally weighted
  - Uncertainty is integrated over models



Communication of uncertainty

- The integrated model can be used to calculate risk metrics
- Other usual methods can also be used



The IPHC decision table

2025 Alternative				Status quo -10%	Status quo -5%	Status quo	$F_{46\%}$	3-Year Surplus	Status quo +10%	Reference $F_{43\%}$	MEY proxy	MSY proxy	
Total mortality (M lb)			0.0	21.8	33.6	35.4	37.1	37.8	39.2	40.7	41.5	46.1	55.1
TCEY (M lb)			0.0	20.0	31.5	33.3	35.3	35.9	37.4	38.8	39.6	44.3	53.2
2025 fishing intensity			$F_{100\%}$	$F_{63\%}$	$F_{50\%}$	$F_{48\%}$	$F_{46\%}$	$F_{46\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{40\%}$	$F_{35\%}$
Fishing intensity interval			--	41-75%	28-65%	27-63%	26-62%	25-61%	24-60%	23-59%	23-59%	21-56%	17-51%
Stock Trend (spawning biomass)	In 2026	Is less than 2025	<1	4	30	36	41	43	48	53	56	69	87	a
		Is 5% less than 2025	<1	<1	5	7	10	11	14	16	18	28	49	b
	In 2027	Is less than 2025	<1	7	34	39	44	46	50	54	57	68	86	c
		Is 5% less than 2025	<1	2	17	21	25	26	30	33	36	47	69	d
	In 2028	Is less than 2025	<1	7	33	38	44	45	50	54	57	69	86	e
		Is 5% less than 2025	<1	3	21	25	29	31	35	39	42	54	76	f
Stock Status (Spawning biomass)	In 2026	Is less than 30%	26	27	27	28	28	28	28	28	28	28	29	g
		Is less than 20%	2	6	10	11	12	12	13	14	14	16	19	h
	In 2027	Is less than 30%	25	25	26	26	26	26	26	27	27	27	28	i
		Is less than 20%	<1	2	8	9	10	10	11	12	13	16	21	j
	In 2028	Is less than 30%	18	25	25	26	26	26	26	26	26	27	28	k
		Is less than 20%	<1	1	7	8	9	10	11	12	13	16	22	l
Fishery Trend (TCEY)	In 2026	Is less than 2025	0	7	31	34	38	40	43	47	49	60	81	m
		Is 10% less than 2025	0	7	31	34	38	39	43	47	49	60	80	n
	In 2027	Is less than 2025	0	6	30	33	37	39	42	46	49	61	82	o
		Is 10% less than 2025	0	6	30	33	37	38	42	46	48	60	81	p
	In 2028	Is less than 2025	0	6	29	33	37	38	42	46	49	61	82	q
		Is 10% less than 2025	0	5	29	33	37	38	42	46	49	61	82	r
Fishery Status (Fishing Intensity)	In 2025	Is above $F_{43\%}$	0	8	32	36	40	41	44	48	50	60	79	s

Yields: low → high

Risk metrics

Estimated risks

Harvest decision table

2025 Alternative					Status quo -25%	Status quo -15%	Status quo -10%	Status quo -5%	Status quo	$F_{46\%}$	3-Year Surplus	Status quo +10%	Reference $F_{43\%}$	MEY proxy	MSY proxy	
Total mortality (M lb)			0.0	21.8	28.3	31.8	33.6	35.4	37.1	37.8	39.0	40.7	41.7	46.1	55.1	
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Fishing intensity interval			--	41-75%	33-69%	30-66%	28-65%	27-63%	26-62%	25-62%	25-61%	24-60%	23-59%	21-56%	17-51%	
Stock Trend (spawning biomass)	In 2026	Is less than 2025	<1	5	16	26	31	37	43	45	49	54	57	70	88	a
		Is 5% less than 2025	<1	<1	2	4	6	8	11	12	14	17	19	29	50	b
	In 2027	Is less than 2025	<1	7	21	30	35	40	45	47	50	55	58	69	86	c
		Is 5% less than 2025	<1	2	8	14	18	22	26	27	30	34	37	48	70	d
	In 2028	Is less than 2025	<1	8	20	30	35	40	45	47	50	55	58	70	87	e
		Is 5% less than 2025	<1	3	11	18	22	26	30	32	36	40	43	55	77	f
Stock Status (Spawning biomass)	In 2026	Is less than 30%	26	26	27	27	27	27	27	27	28	28	28	28	29	g
		Is less than 20%	1	5	7	8	9	10	10	11	11	12	12	14	18	h
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	In 2027	Is less than 2025	0	6	23	27	30	33	37	38	41	46	48	60	81	o
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Fishery Status (Fishing intensity)	In 2025	Is above $F_{43\%}$	0	7	25	29	32	35	39	41	44	47	50	59	78	s

A few things we have learned

- No matter how much you are in love with it, your model may dump you if enough data come along to distract it
- Ensembles aren't more work – they are actually less work, and don't require that last painful decision to assign zero weight to all but one model
- Results from multiple-models aren't fundamentally any different than those from single models
- Clear communication is still the hardest part of stock assessment

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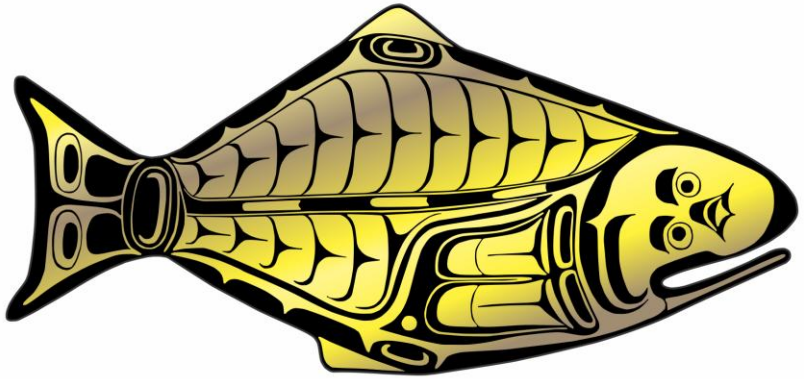

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https://www.iphc.int/

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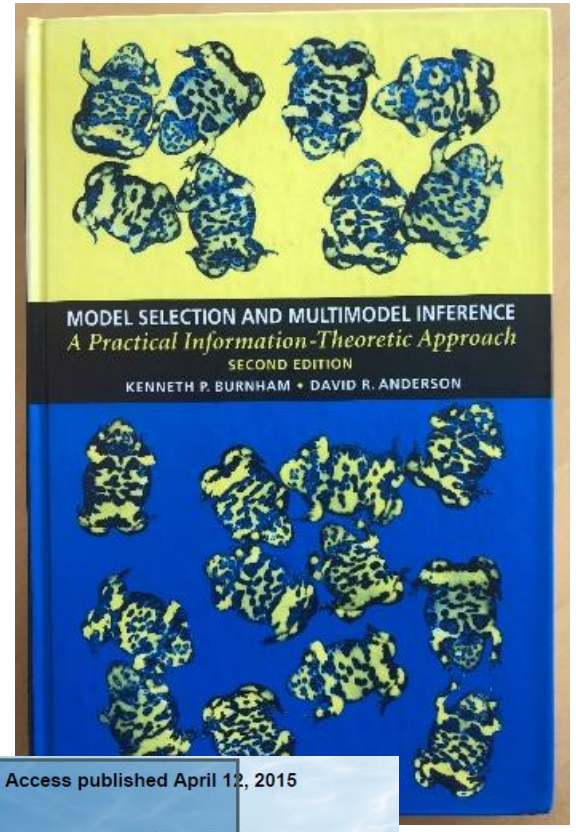
Fundamental references

Burnham, K.P., and Anderson, D.R. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd Edition. Springer-Verlag, New York, 488 p.

Hooten, M.B., and Hobbs, N.T. 2015. A guide to Bayesian model selection for ecologists. Ecological Monographs **85**(1): 3-28.

Stewart, I.J., and Martell, S.J.D. 2015. Reconciling stock assessment paradigms to better inform fisheries management. ICESJMS.



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Reconciling stock assessment paradigms to better inform fisheries management

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Some links for more information

Stock assessment web-page (including all assessments back to 1978):
https://www.iphc.int/management/science-and-research/stock-assessment

2022 stock assessment summary:
https://www.iphc.int/uploads/pdf/am/am099/iphc-2023-am099-11.pdf

2022 data overview:
https://www.iphc.int/uploads/pdf/sa/2023/iphc-2023-sa-02.pdf

2022 stock assessment:
https://www.iphc.int/uploads/pdf/sa/2023/iphc-2023-sa-01.pdf

2022 Assessment review document (more technical information):
https://www.iphc.int/uploads/pdf/srb/srb020/iphc-2022-srb020-07.pdf