Evaluating benchmarks of biological status for Pacific salmon under climate-driven changes in stock productivity and limited data

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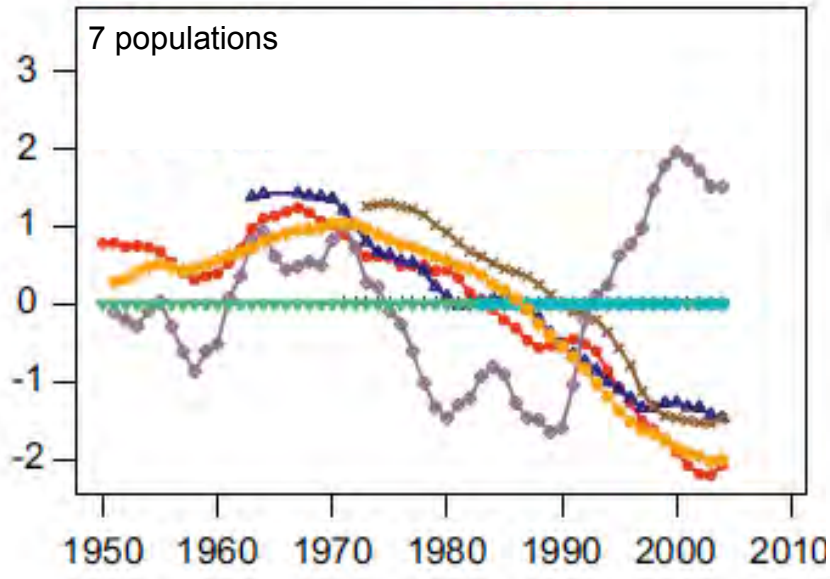
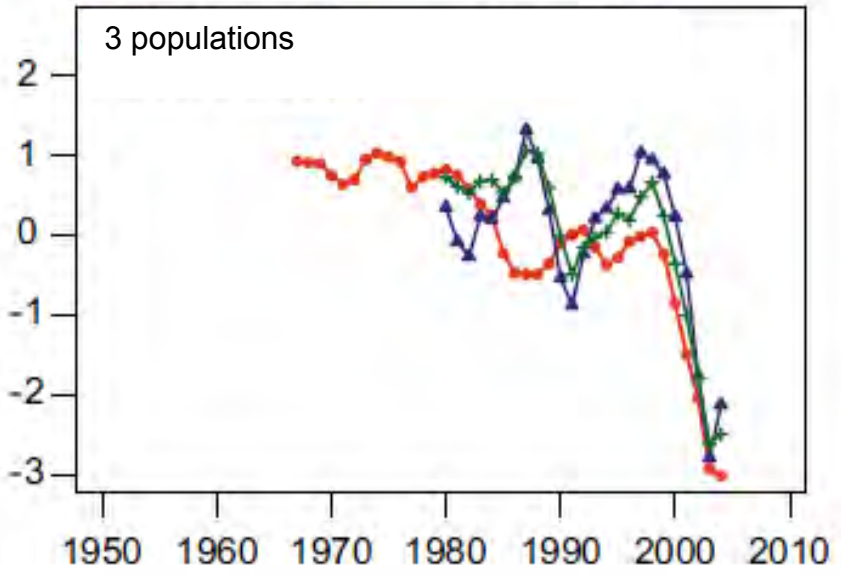
Recent declines in productivity

Sockeye salmon

Fraser River, BC



Puget Sound, WA and Vancouver Island, BC



Scaled productivity index

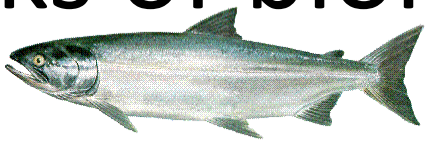
Brood year

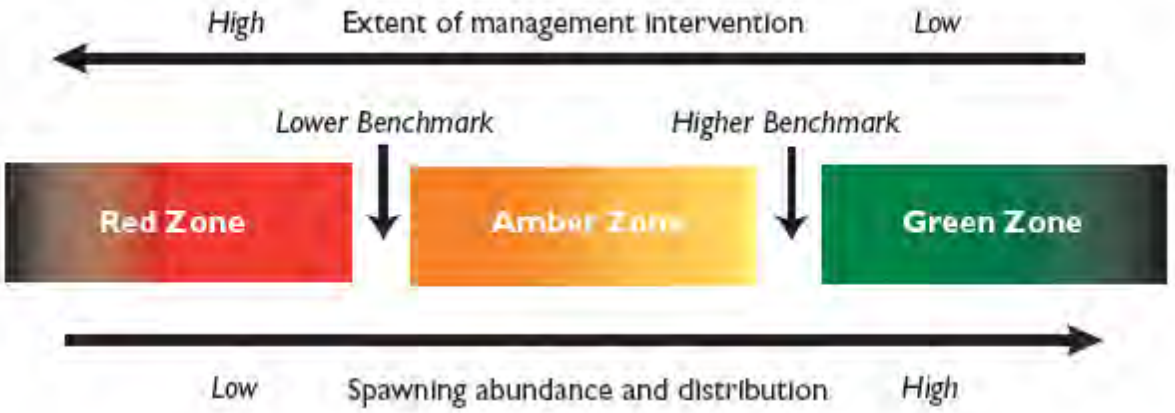
(Peterman and Dorner 2012)

Given large-scale declines in productivity and no signs of recovery despite reductions in harvest pressure,

Are current assessment methods and management strategies robust to these persistent changes?

Benchmarks of biological status





Canada's Wild Salmon Policy (Holt et al. 2009):

Lower benchmark

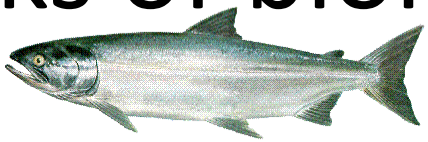
S_{gen}: spawner abundances that will result in recovery to S_{MSY} within 1 generation

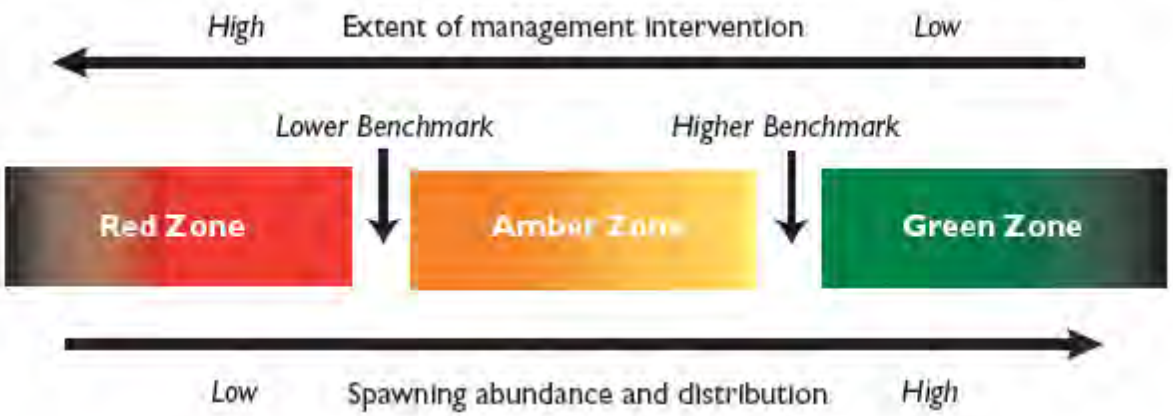
Fisheries and Ocean's Canada Precautionary Approach (2009):

40% of S_{MSY}

(DFO 2005; Holt et al. 2009)

Benchmarks of biological status





Canada's Wild Salmon Policy (Holt et al. 2009):

Lower benchmark

S_{gen}: spawner abundances that will result in recovery to S_{MSY} within 1 generation

Relatively low probability of extirpation and high probability of recovery compared with other candidate lower benchmarks under scenarios of reduced productivity

Fisheries and Ocean's Canada Precautionary Approach (2009):

40% of S_{MSY}

(DFO 2005; Holt et al. 2009)

Data-limited populations

Pervasive

- In Canada, ~75% assessment units of Pacific salmon have insufficient data to estimate stock-recruitment relationships and associated benchmarks

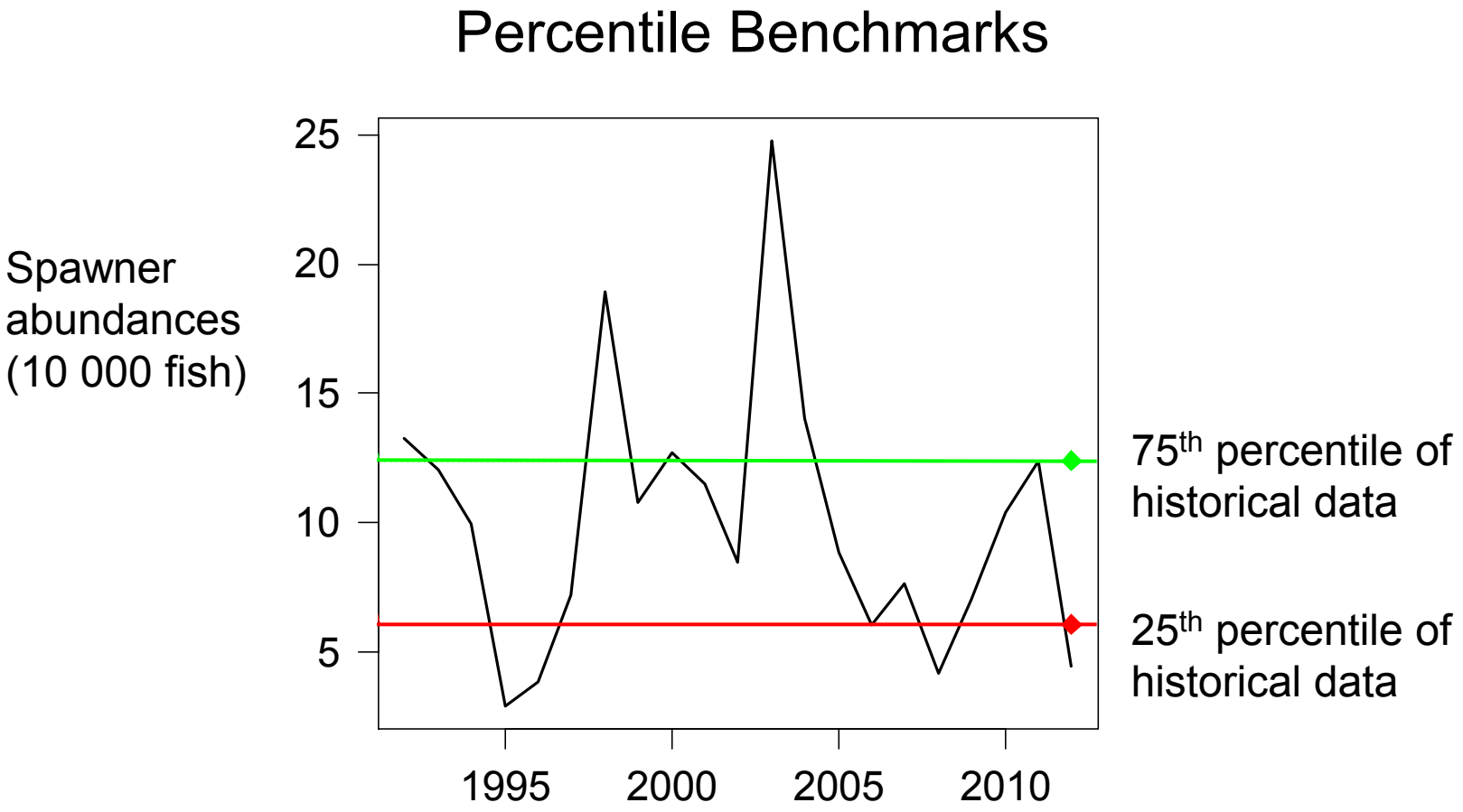
Limitations increasing

- Reductions in fishing pressure will result in loss of fishery-derived data

Alternatives

- Benchmarks derived from time-series of spawner abundances have been proposed, but have not been rigorously evaluated

Data-limited population



(Eggers 2008)

Objectives

1. Evaluate the performance of lower benchmarks derived for data-limited populations of Pacific salmon based on spawner time-series alone against those derived from data-intensive methods, given changes in stock productivity

Two approaches:

- Status against benchmarks used to inform annual harvest decisions
- Benchmarks inform biological or conservation status independent of harvest decisions

Objectives

1. Evaluate the performance of lower benchmarks derived for data-limited populations of Pacific salmon based on spawner time-series alone against those derived from data-intensive methods, given changes in stock productivity
2. Evaluate effects of outcome uncertainty (from implementing management actions) on relative performance
3. Evaluate effects reductions in survey coverage on relative performance
4. Identify if results are robust to assumptions about straying among sub-populations and meta-population stock structure

Simulation model developed for a hypothetical population of chum salmon

Initialization: 20% carrying capacity 25 years

Population dynamics sub-model

- 5 sub-populations within an assessment unit
- random variability in recruitment residuals and age-structure
- includes straying

Harvest sub-model

- random variability in outcomes of implementing harvest rule

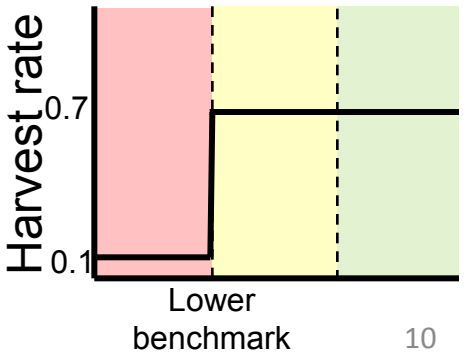
100 years and 1000 MC trials

Observation sub-model

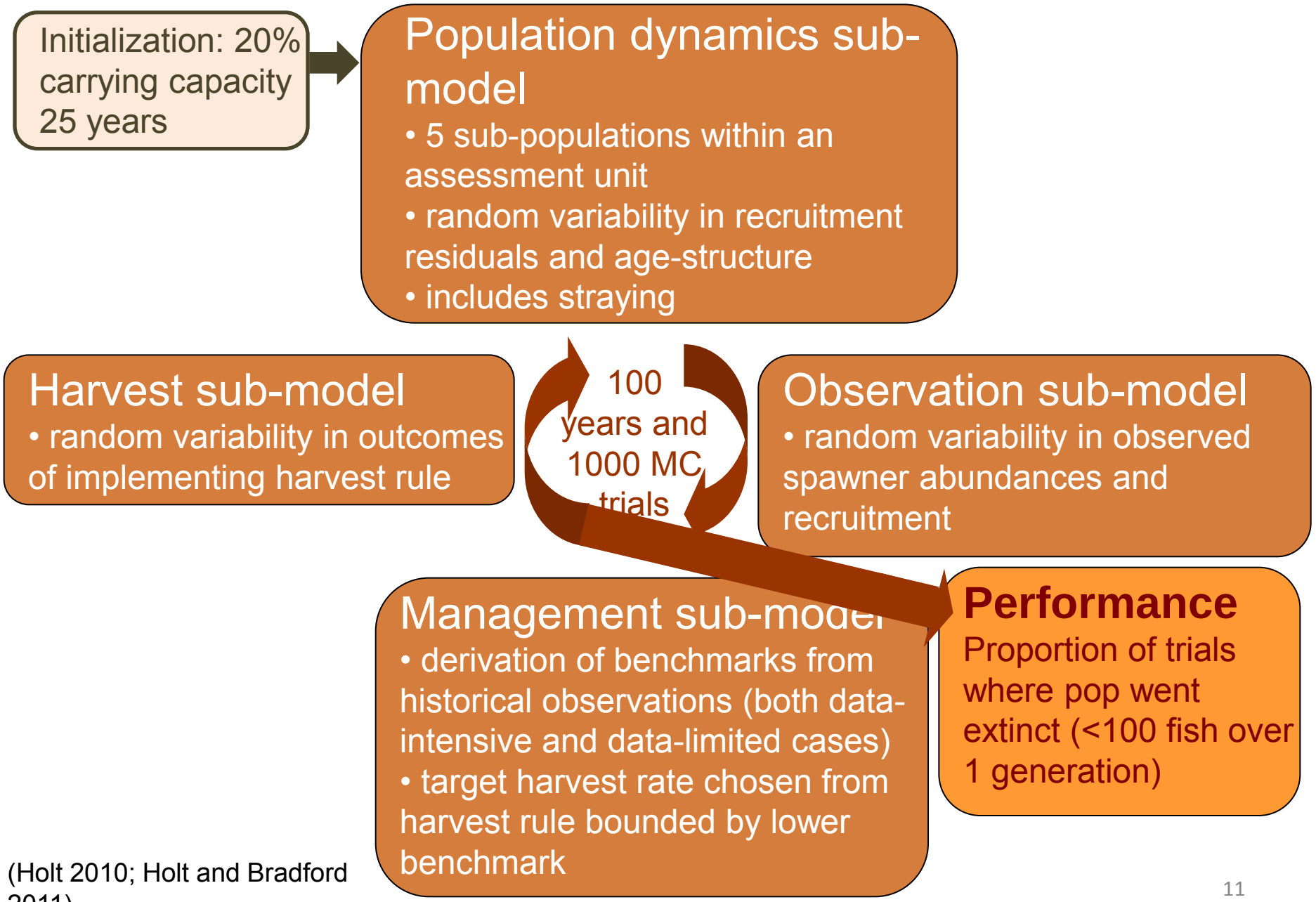
- random variability in observed spawner abundances and recruitment

Management sub-model

- derivation of benchmarks from historical observations (both data-intensive and data-limited cases)
- target harvest rate chosen from harvest rule bounded by lower benchmark



(Holt 2010; Holt and Bradford 2011)



(Holt 2010; Holt and Bradford 2011)

Scenarios

- Three lower benchmarks:

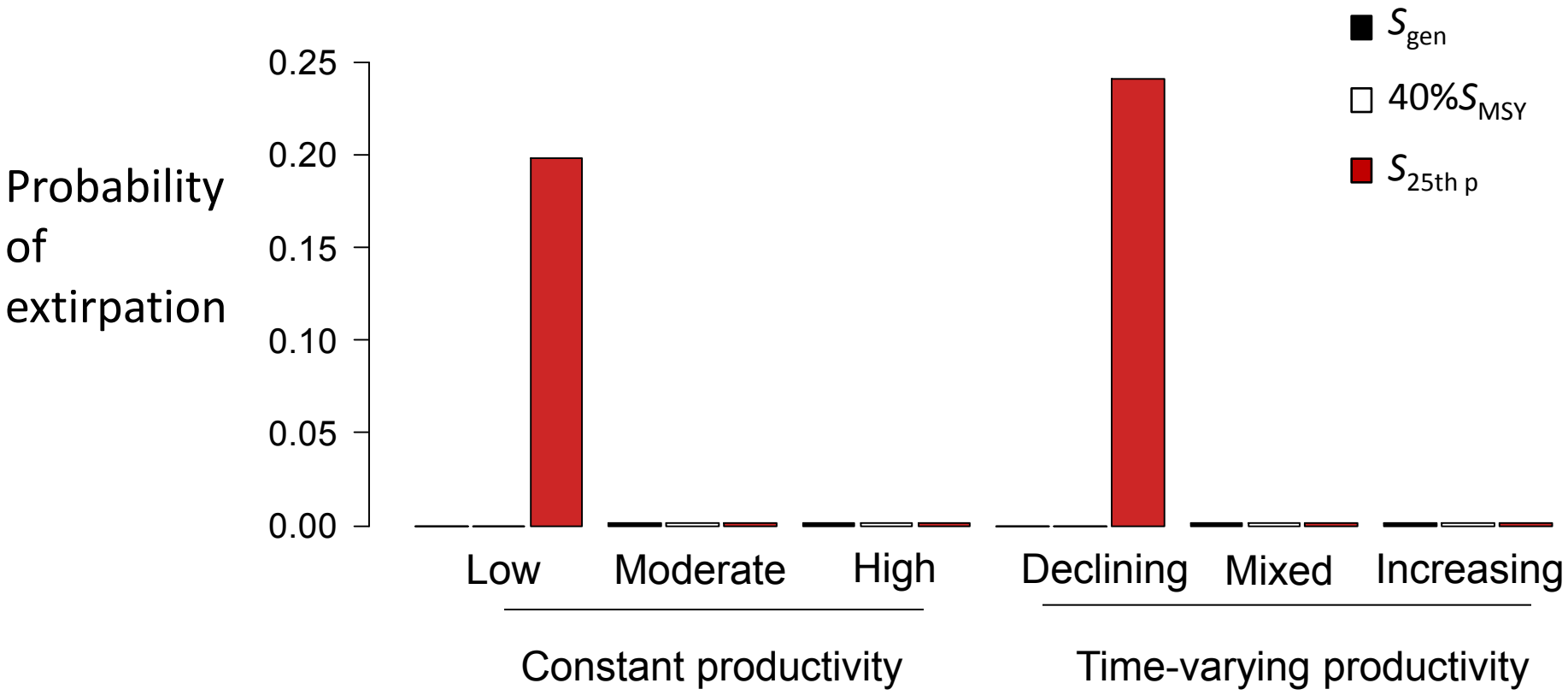
(1) S_{gen}
(2) $40\%S_{MSY}$
(3) $S_{25th\ percentile}$

Data-intensive

Data-limited

	Variable	Base case	Scenarios
Obj.1	Productivity (recruits/spawner at low spawner abundances)	4.5	2, 7.5
Obj.1	Trends in productivity	Stable	From 4.5 to 2 (7.5) over 50 years
Obj.2	Outcome uncertainty (σ_{OU})	0.3	0.5
Obj.3	Survey coverage	100%	50-100%
Obj.4	Straying among sub-populations	2%	0,10%
Obj.4	Autocorrelation in recruitment anomalies	0.4	0.2, 0.6, 0.8
Obj.4	Covariation in recruitment anomalies between pairs of sub-populations (σ_C)	0.4	0, 0.6

Obj 1: Performance of percentile benchmarks sensitive to reductions in productivity



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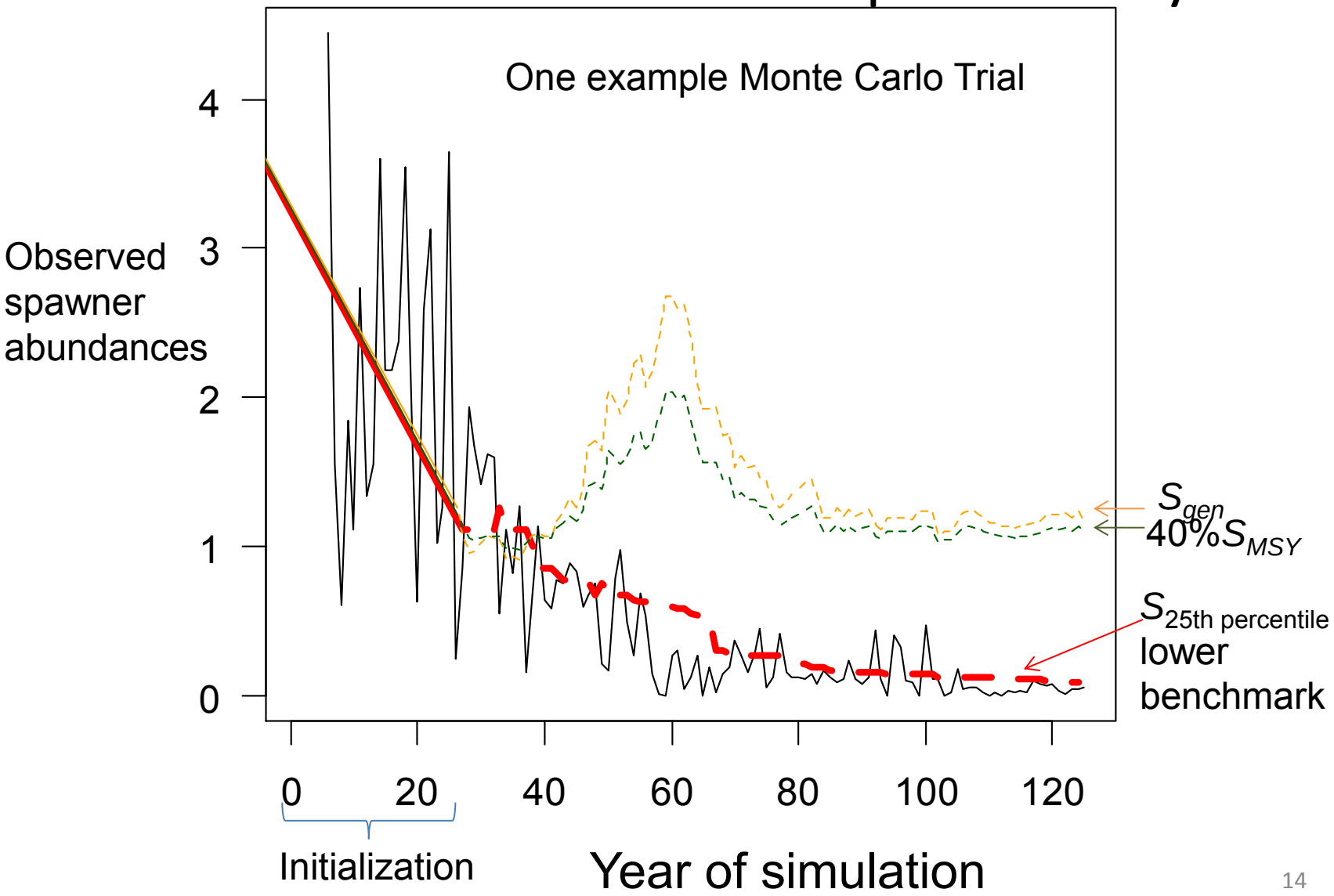
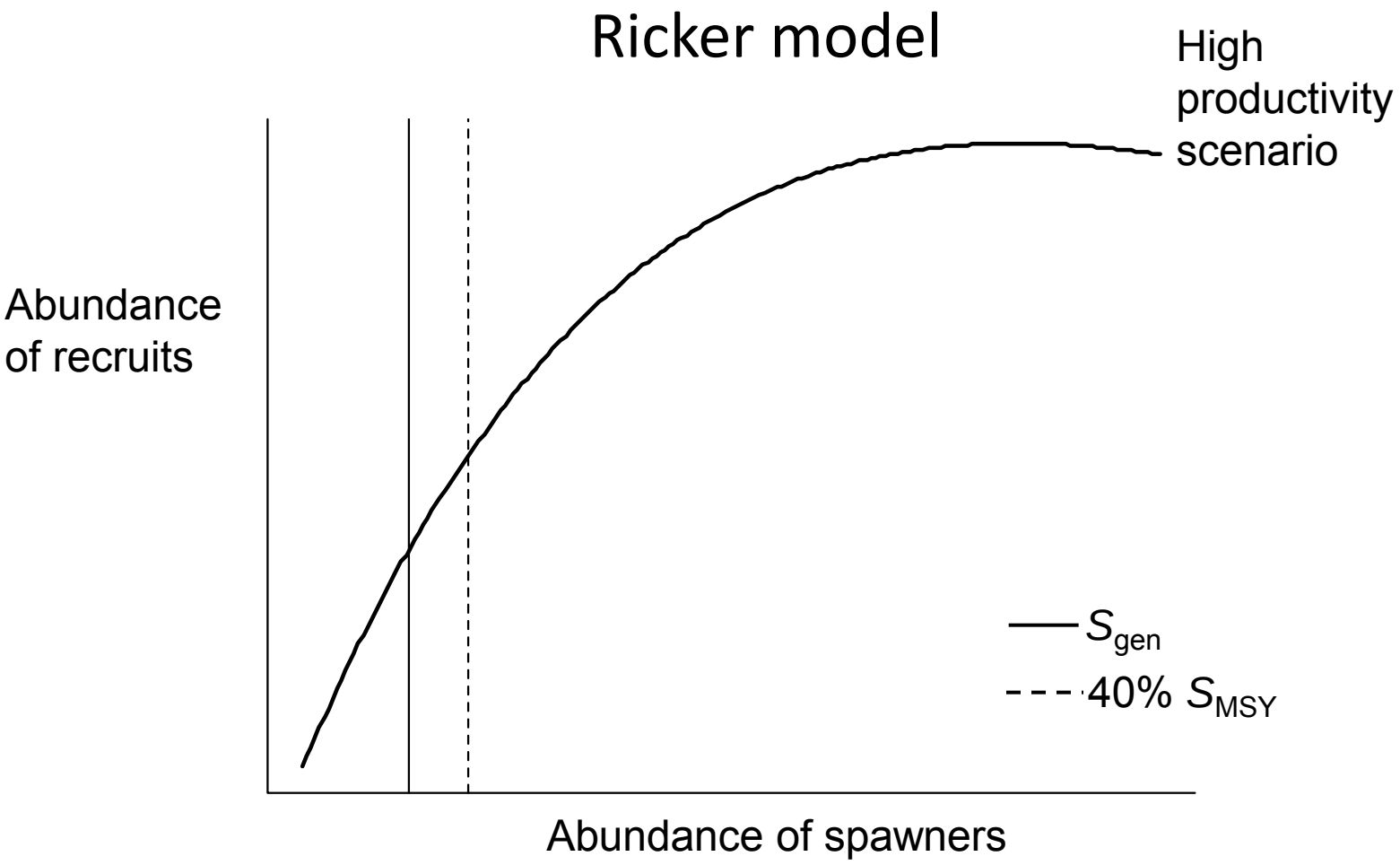


Obj 1: Benchmarks based on spawner-recruit relationship increase as productivity declines



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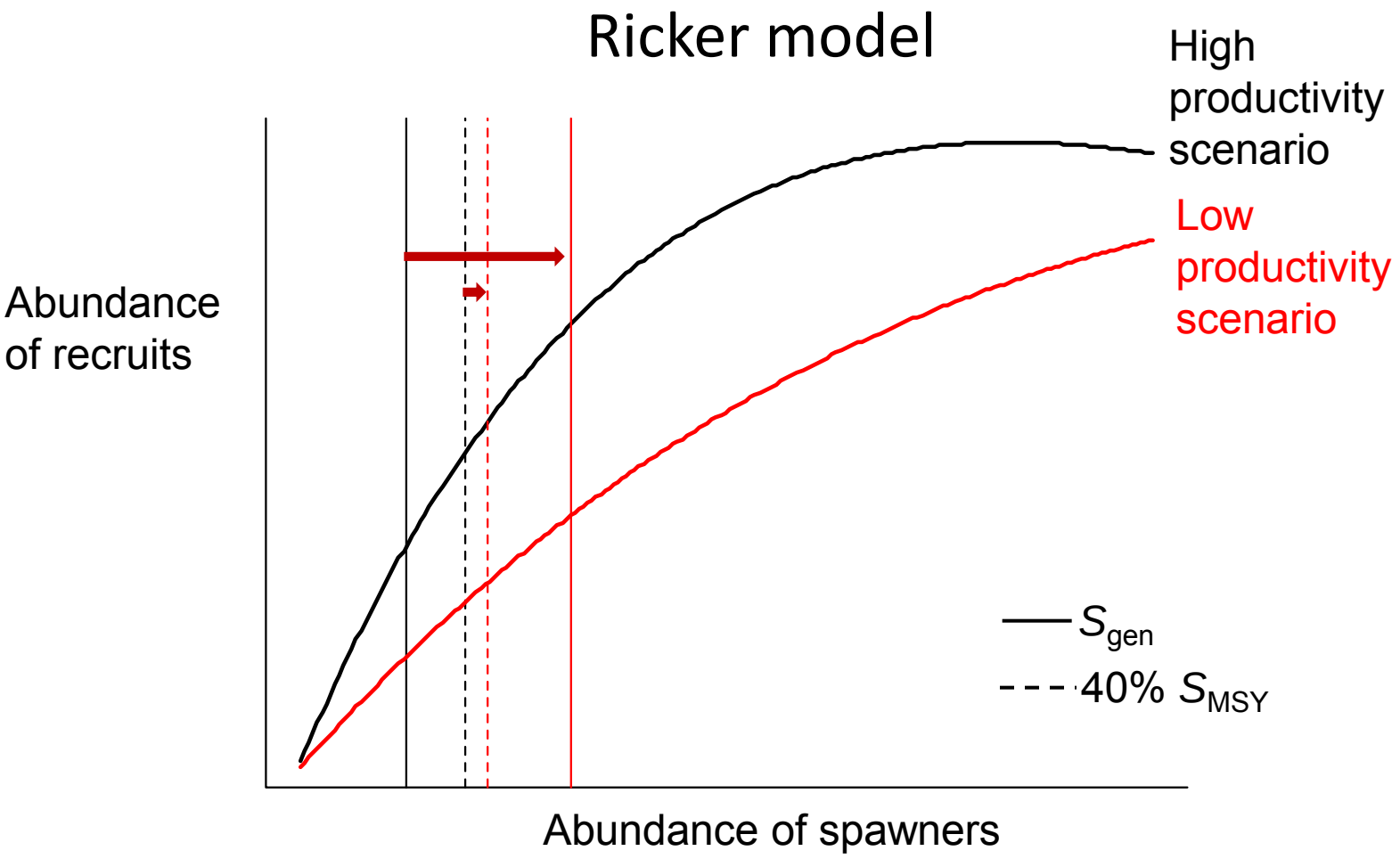
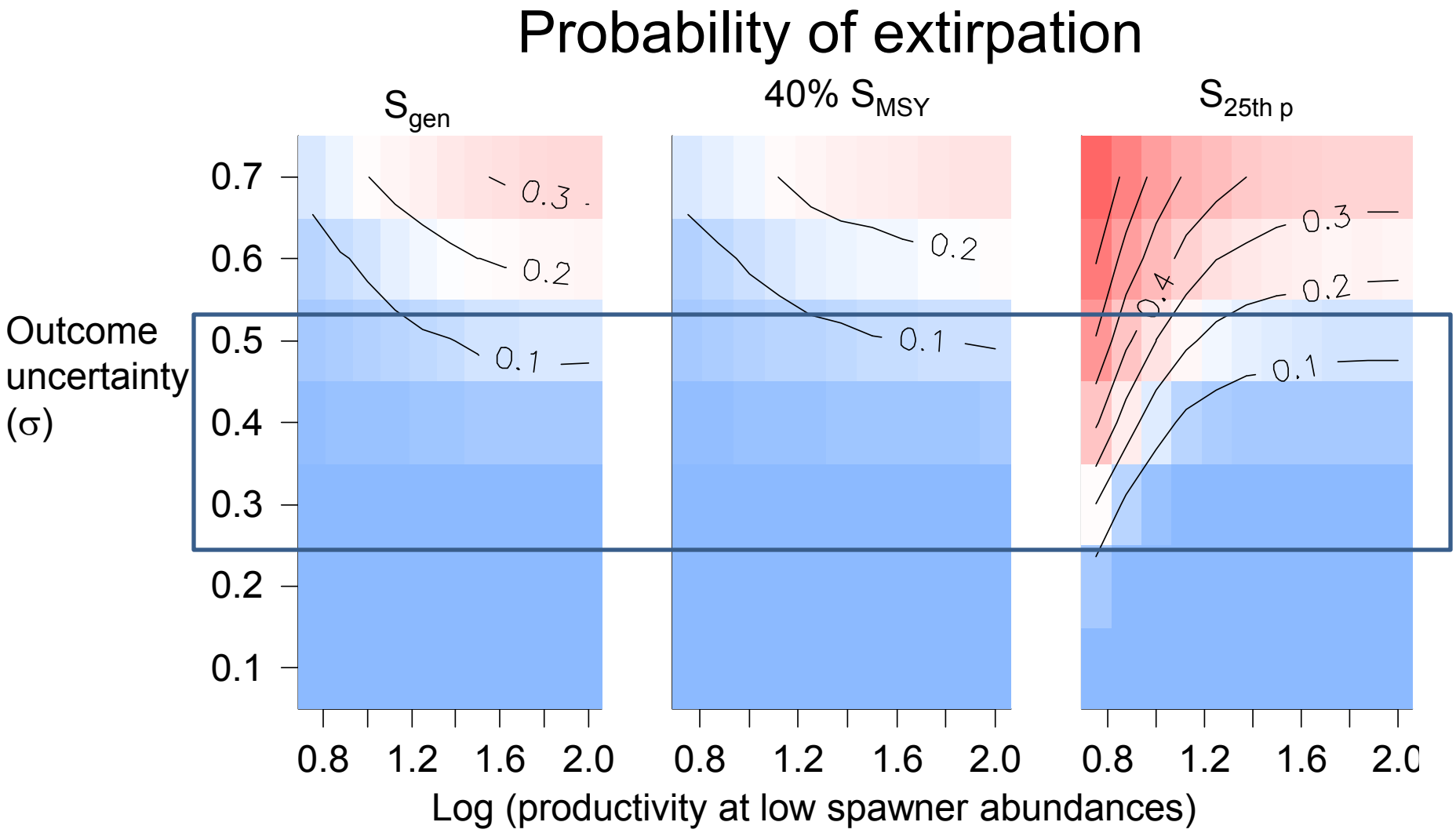


Obj 2: Performance of percentile benchmarks sensitive to outcome uncertainty, especially at low productivity



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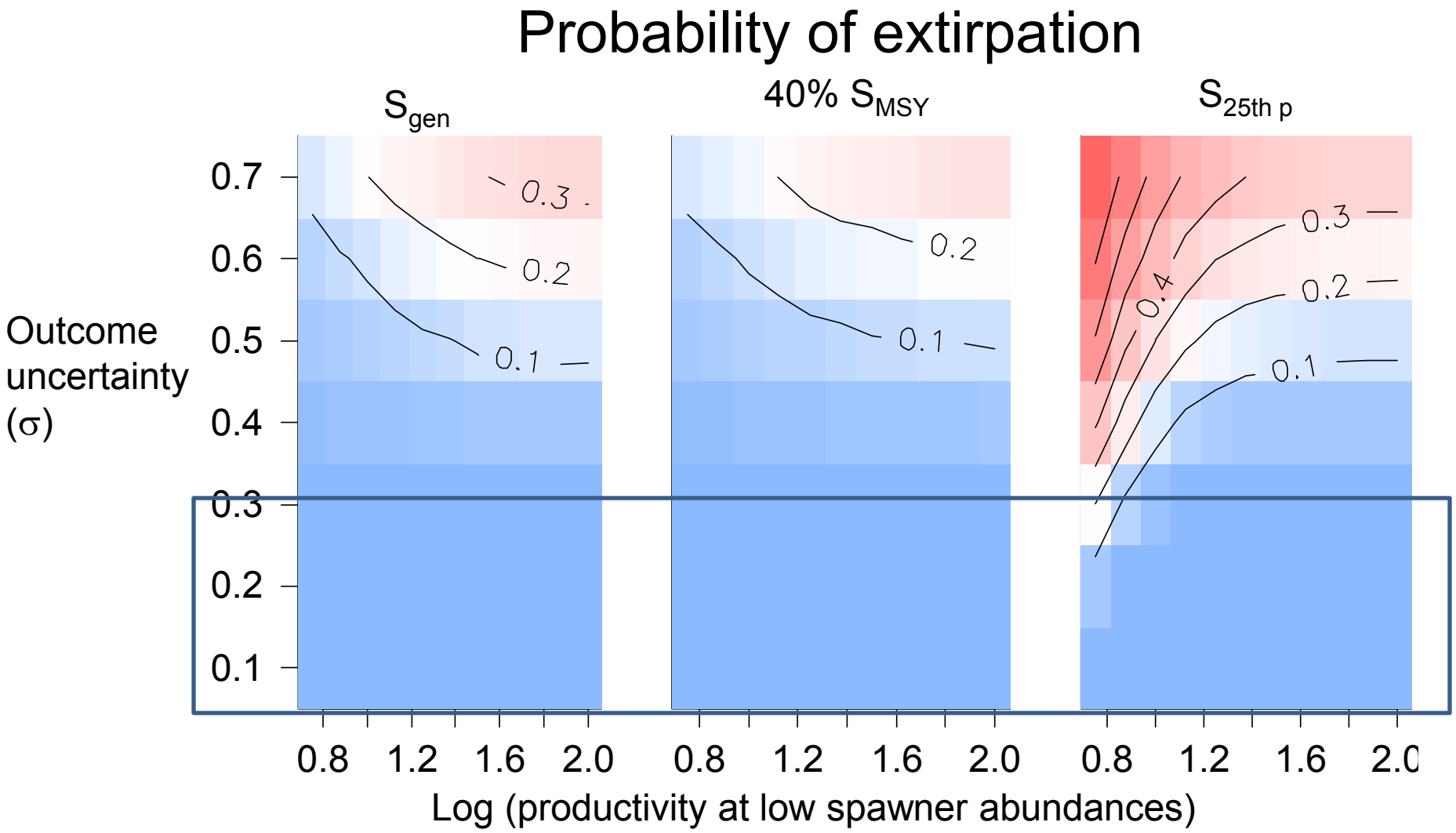

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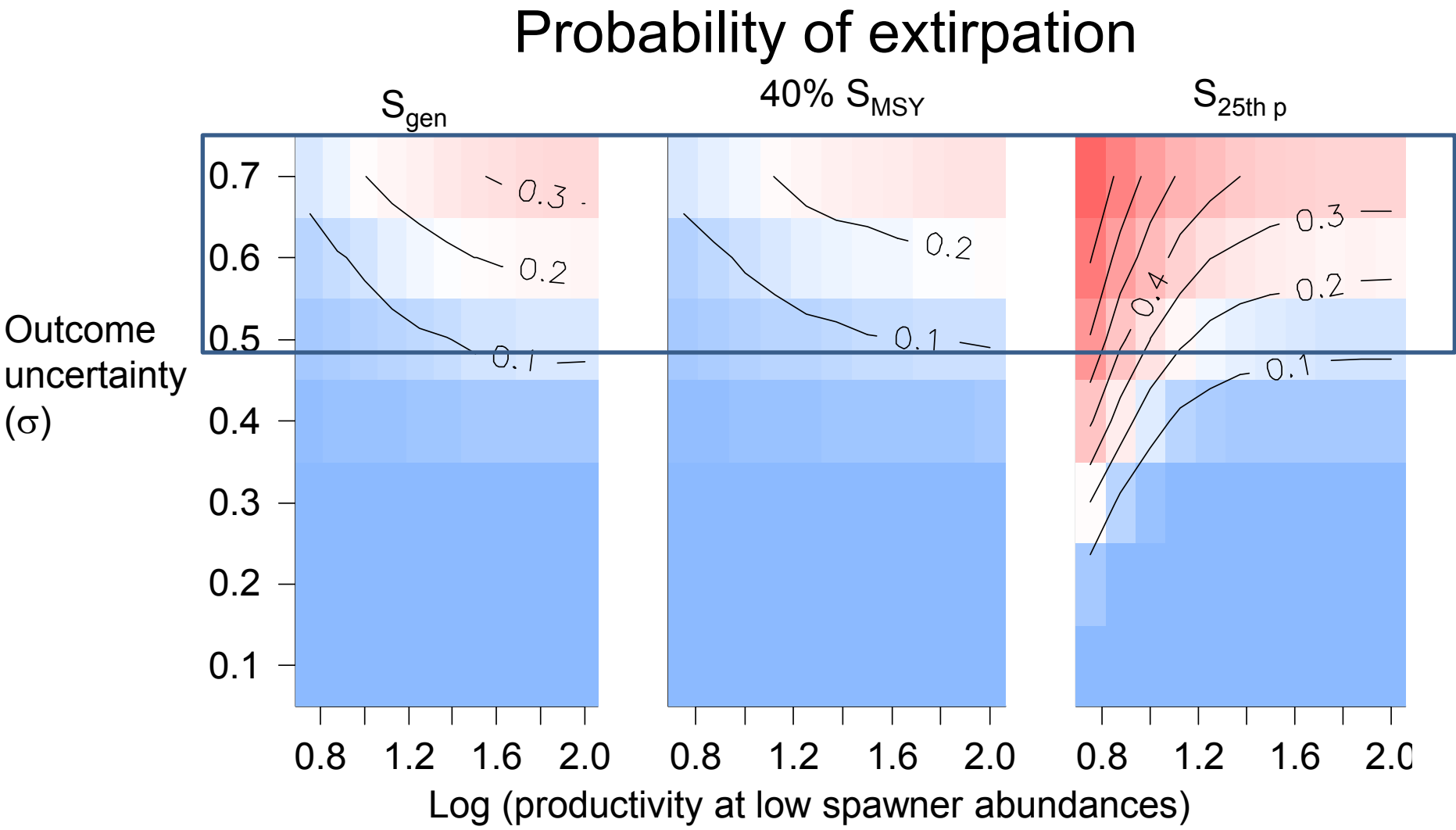
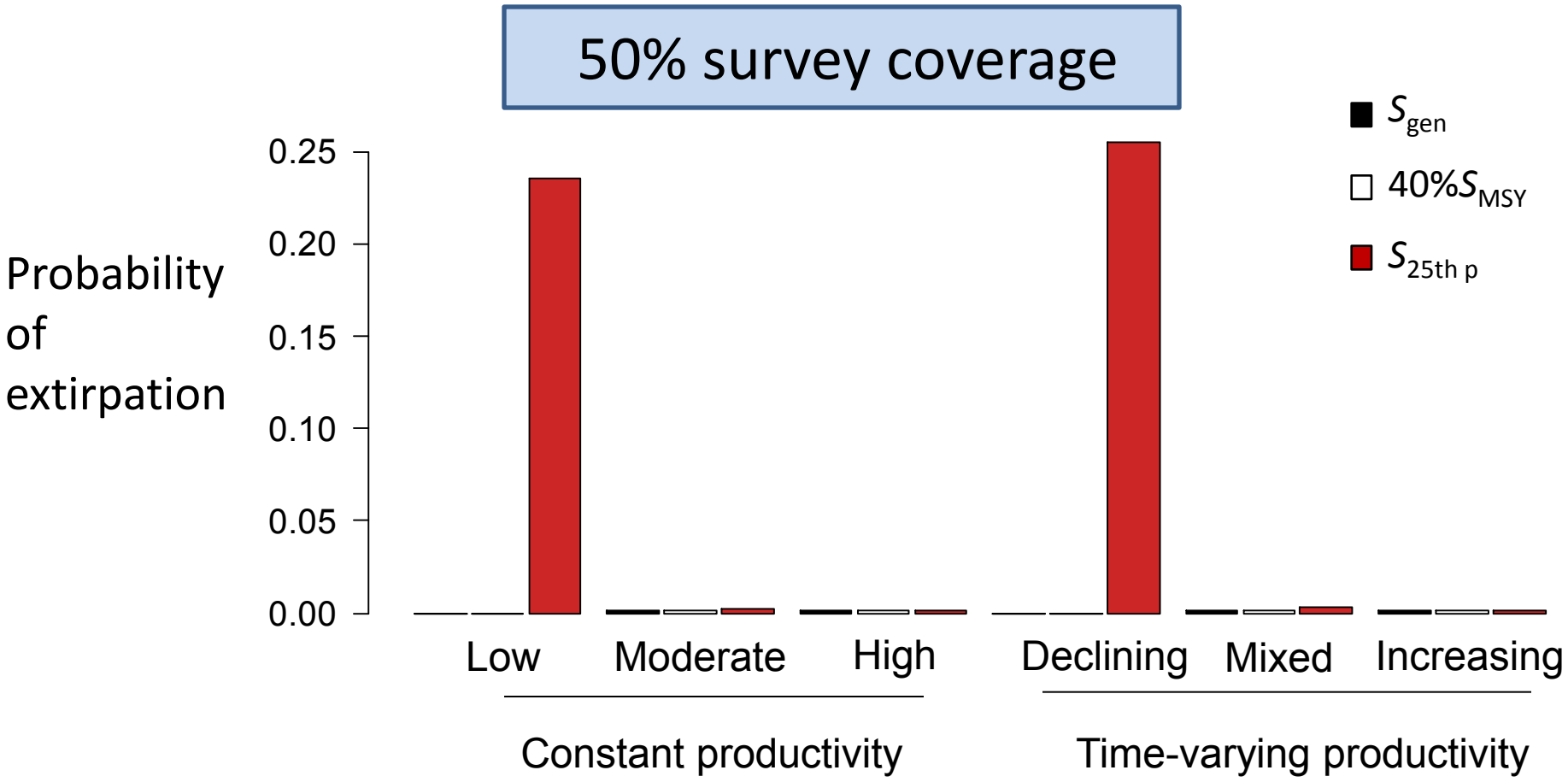
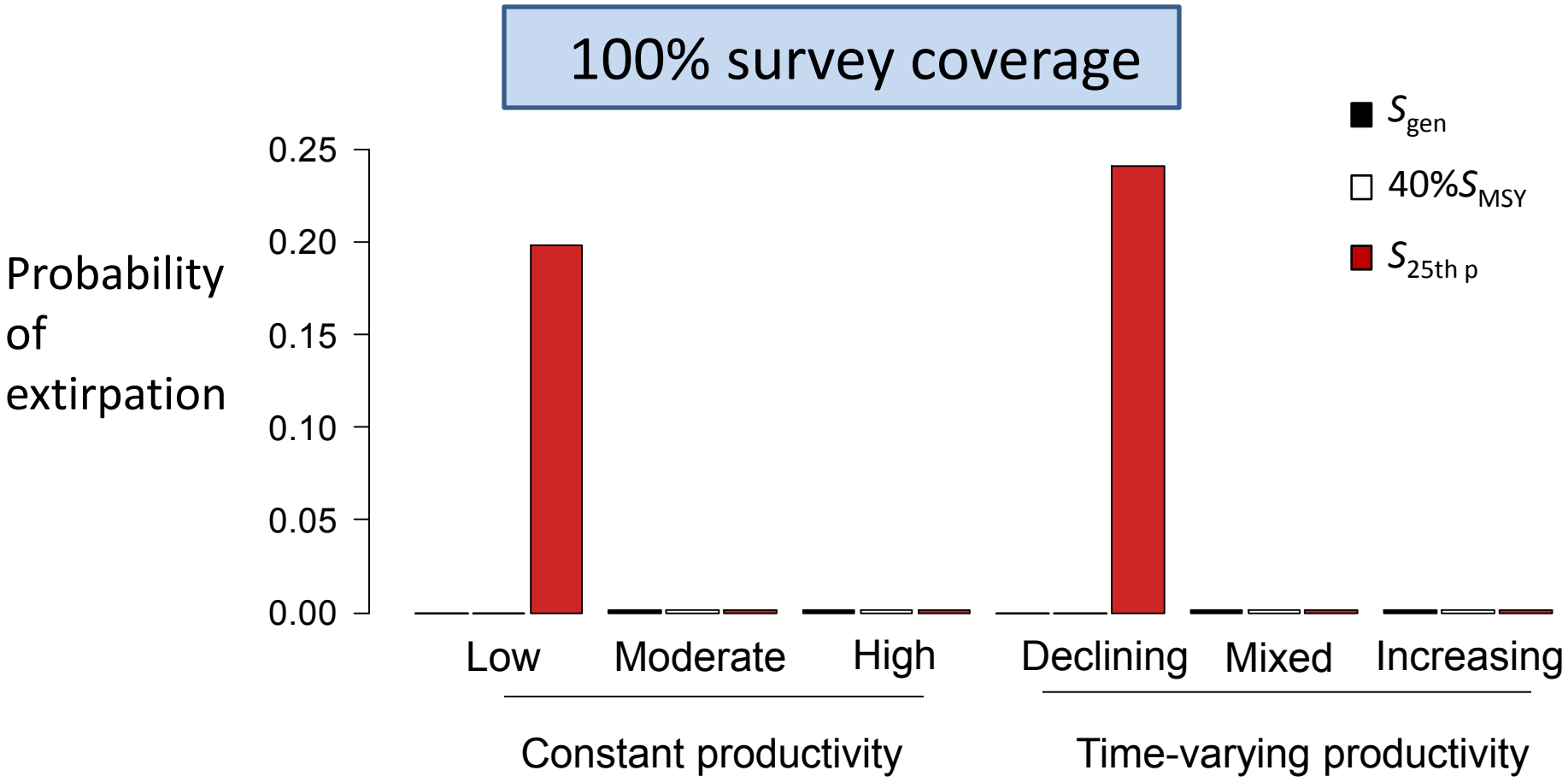


Obj 3: Performance of percentile benchmarks relatively insensitive to survey coverage



Obj 3: Performance of percentile benchmarks not sensitive to survey coverage



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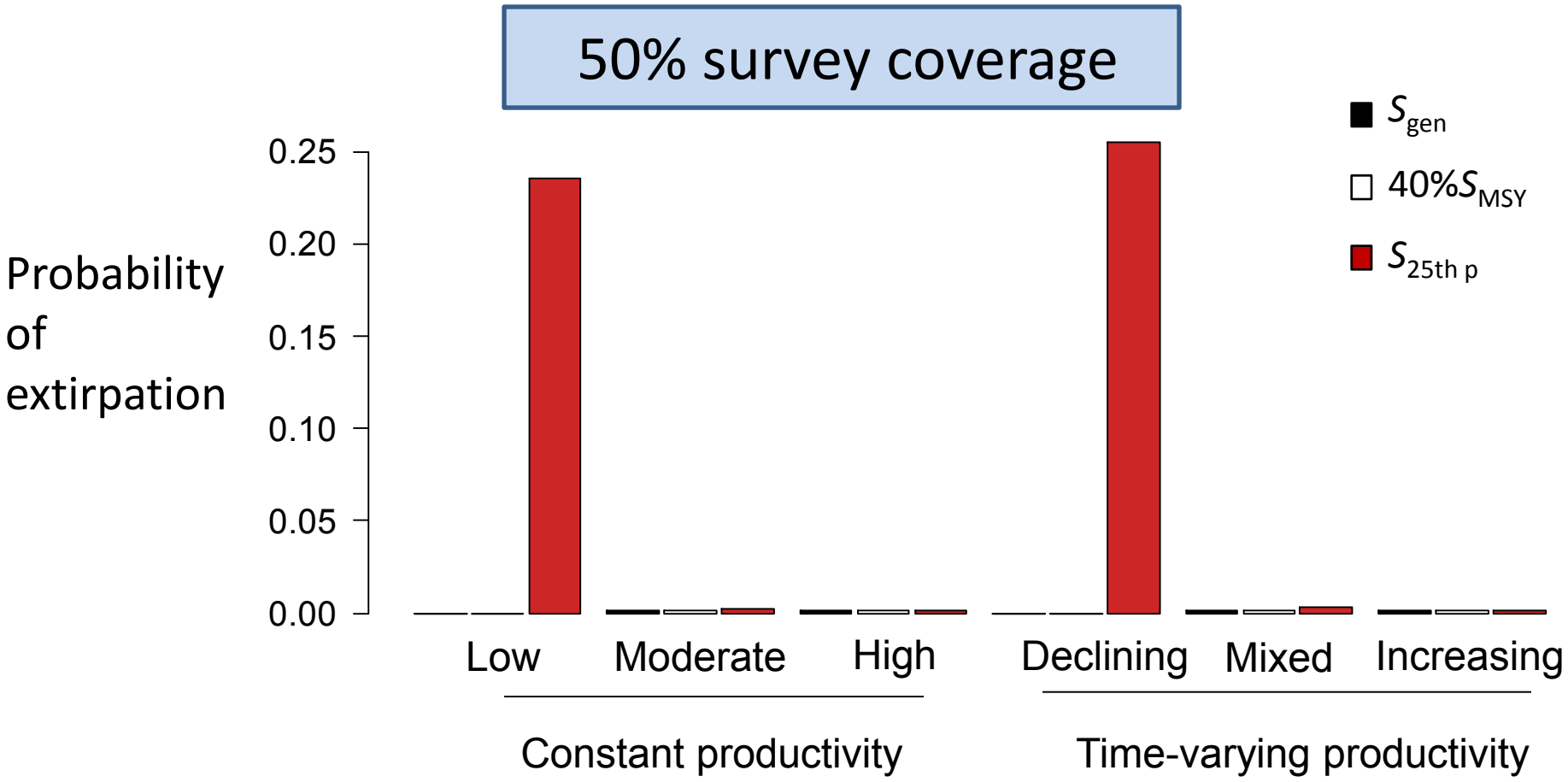
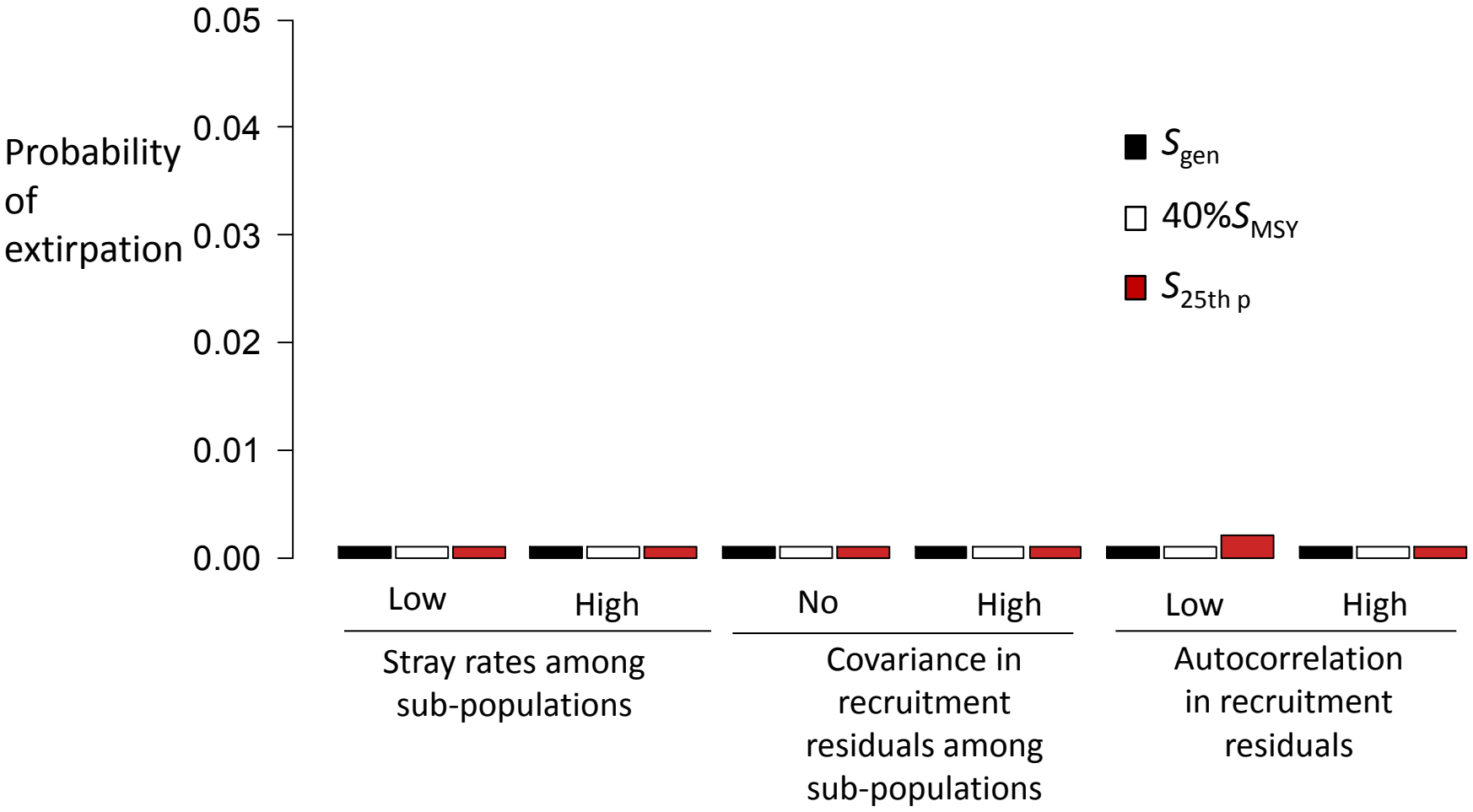


Obj 4: Performance of all benchmarks tend to be insensitive to assumptions about straying and meta-population structure



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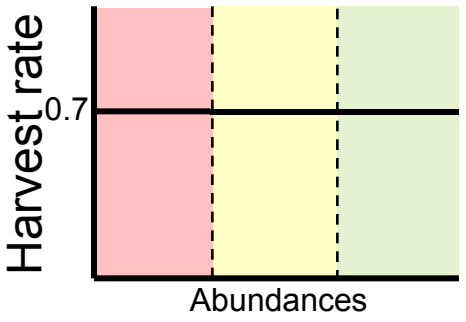

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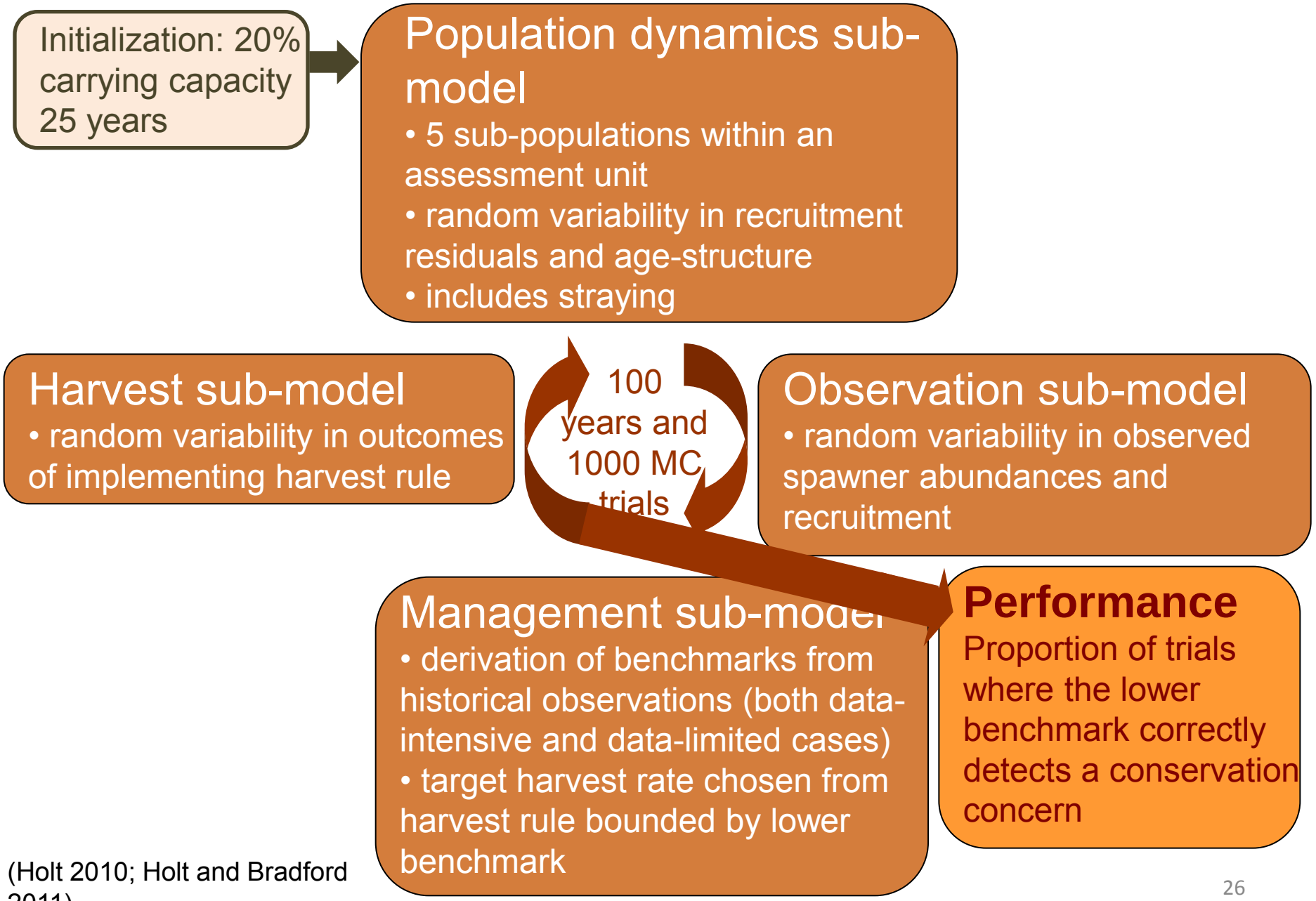

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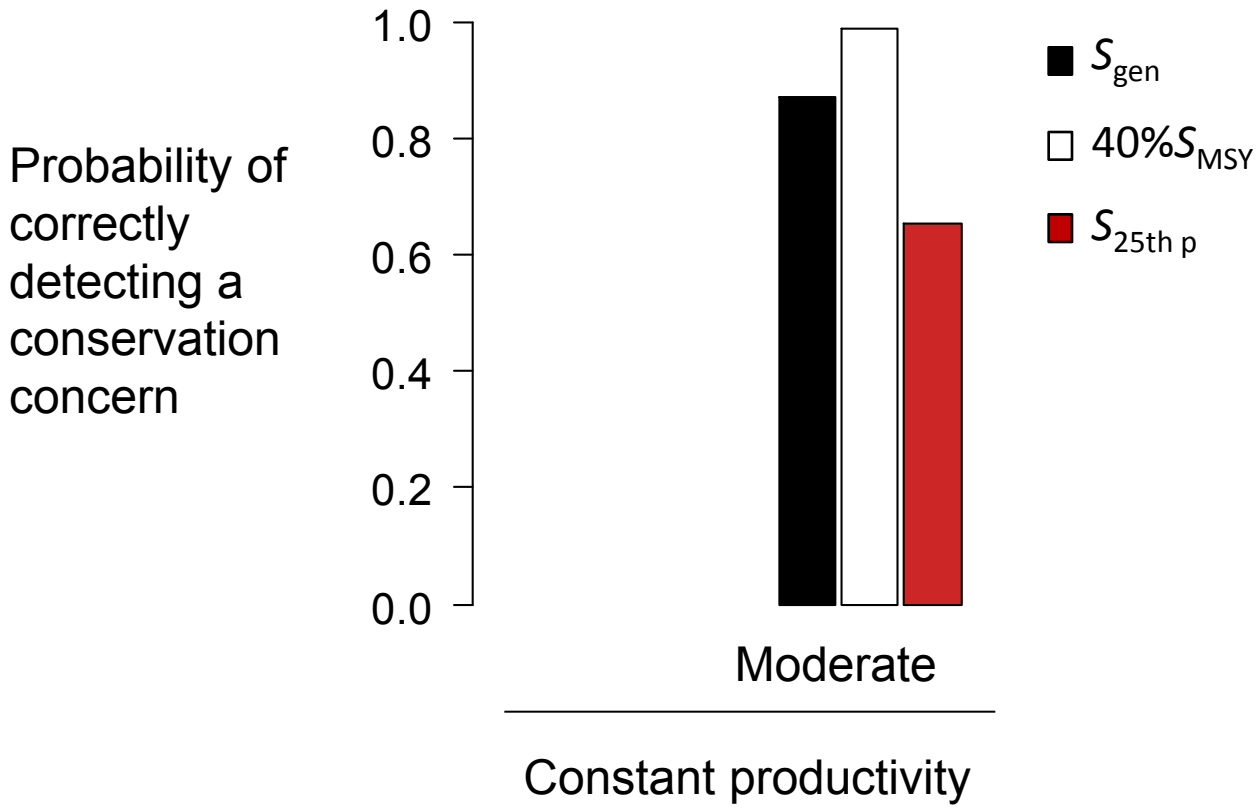
Benchmarks based on percentiles have lower probability of correctly detecting a conservation concern



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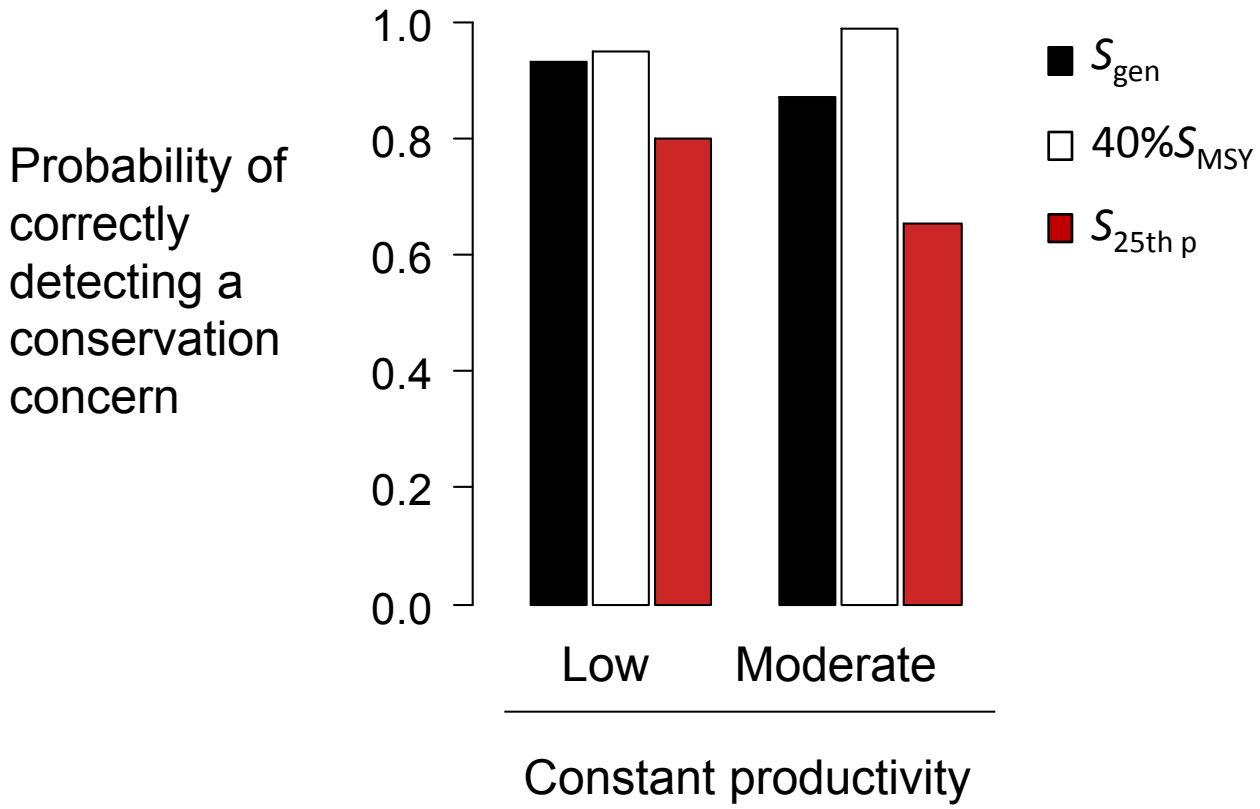

Summary

- Benchmarks derived from percentiles of historical spawner abundances had similar performance to more data-intensive benchmarks under moderate-high and constant or increasing productivity when they are used to inform harvest management
- Percentile-based benchmarks performed poorly when productivity was low or declining
- All benchmarks performed poorly under high outcome uncertainty
- Percentile benchmarks were less able to detect conservation concerns than data-intensive benchmarks

Recommendations

- Benchmarks and reference points are increasingly being developed for data-poor populations in BC and AK from spawner abundances alone. Our results suggest caution when applying benchmarks derived from percentiles of historical time-series where declines in productivity are a concern and outcomes of management actions are uncertain

- Consider adapting benchmarks to account for changes in productivity and/or outcome uncertainty (on going work)

Recommendations

- Uncertainties in outcomes of implementing harvest decision are significant, and should be considered when evaluating management approaches
- Simulation modelling provides powerful tool to evaluate different management and assessment approaches under various future scenarios in climate and other physical/biological conditions
- Also provides tool for communicating uncertainties of impacts of climate changes on various management approaches
  - Transparency about assumptions
  - Can include stakeholder input
  - Range of futures considered
  - Directly related to management needs

Acknowledgements

Chuck Parken, Antonio Velez-Espino, Ann-Marie Huang, Matt Grinnell, Sue Grant, Gérald Chaput, Lyse Godbout from Fisheries and Oceans Canada