Bayesian probability modeling

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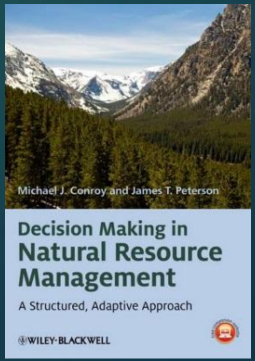


First, some definitions…

Certainty: An event is considered certain if it is 100% likely to happen

Uncertainty: Anything that falls short of absolute certainty

Uncertainty generally incorporated into natural resource decision modeling using probability

Common forms of uncertainty in natural resources management decision making

Linguistic

Epistemic

- Statistical uncertainty
- Observational error
- Structural uncertainty

Reducible

Aleatory

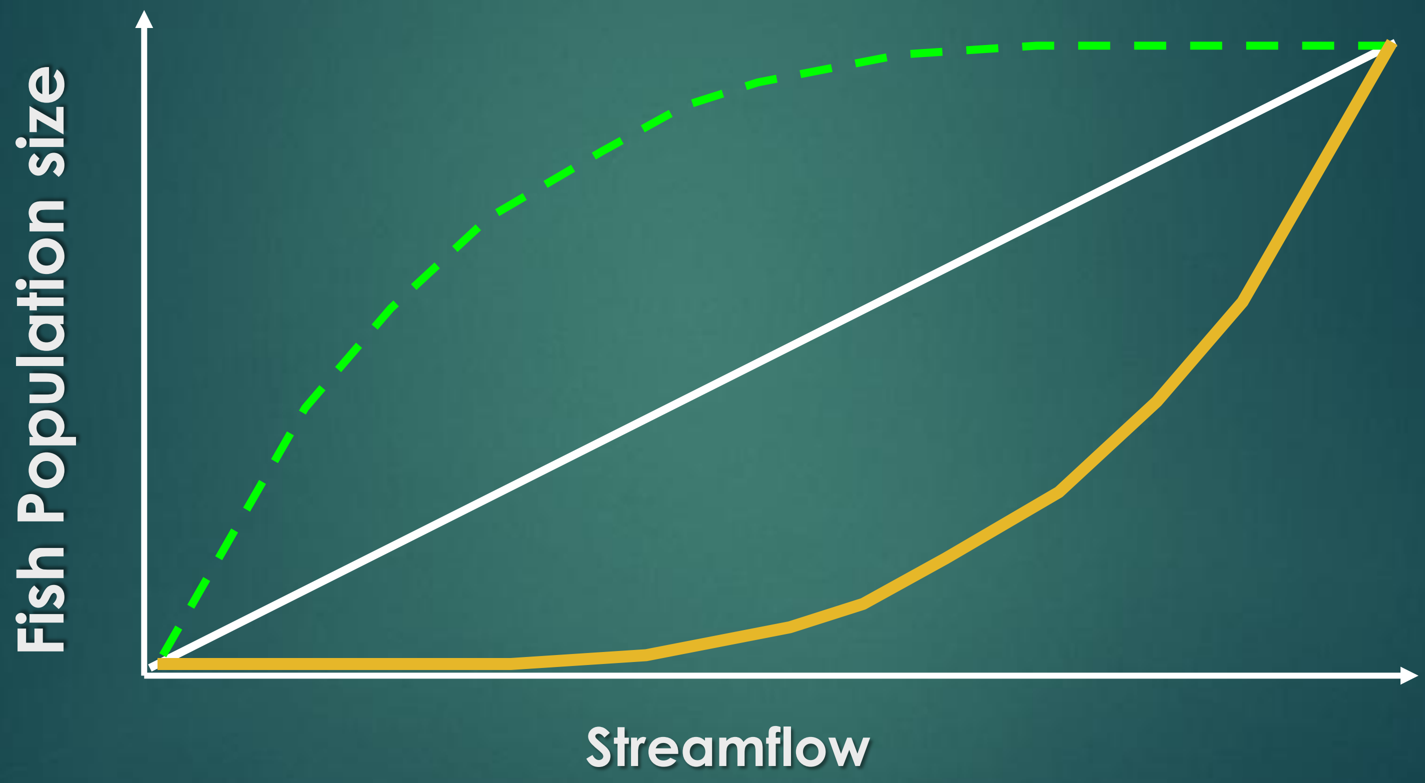
- Environmental variability
- Demographic variability

Irreducible

Often overlooked source of uncertainty

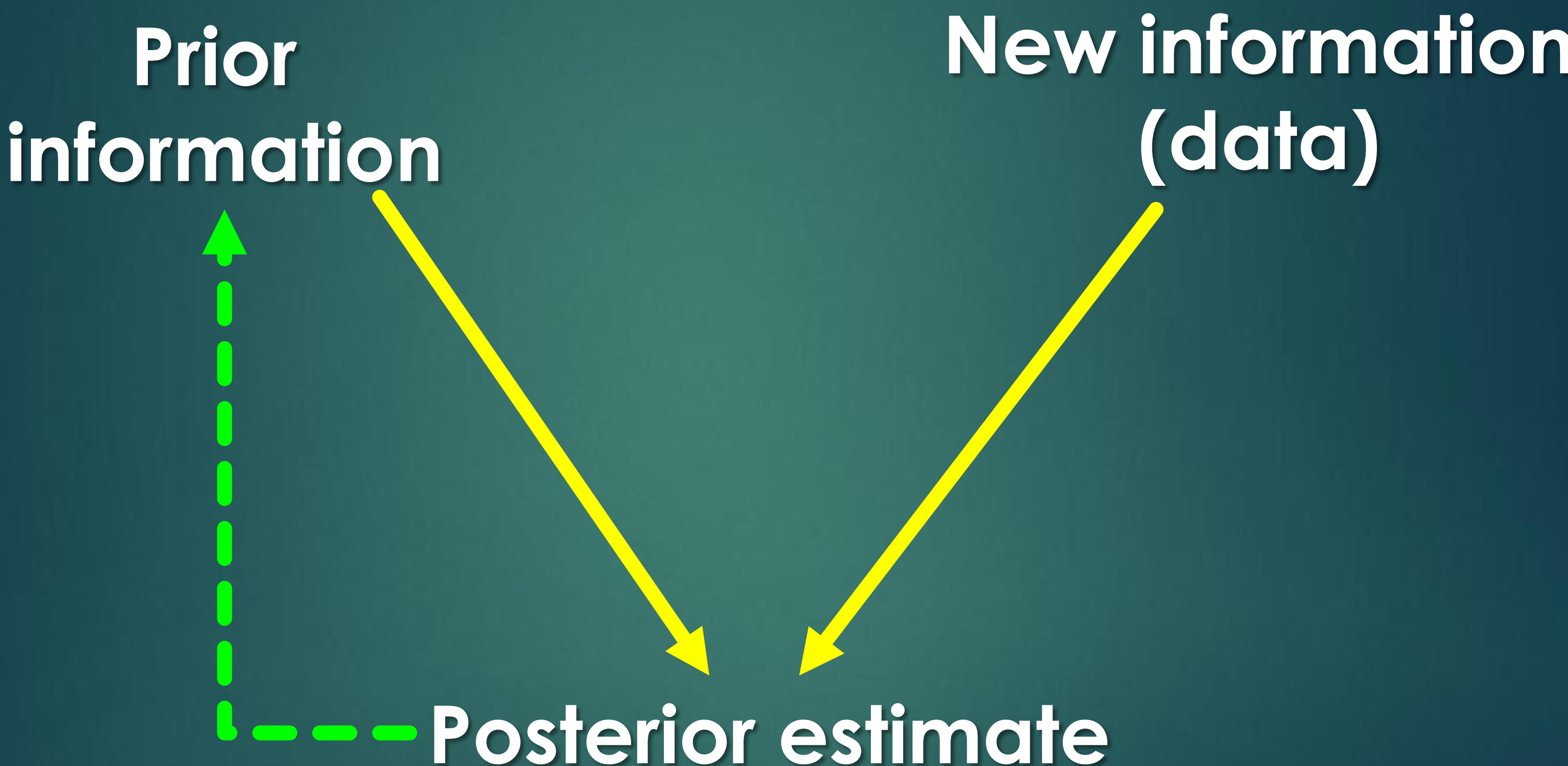
Structural (System) uncertainty

due to incomplete understanding of system dynamics

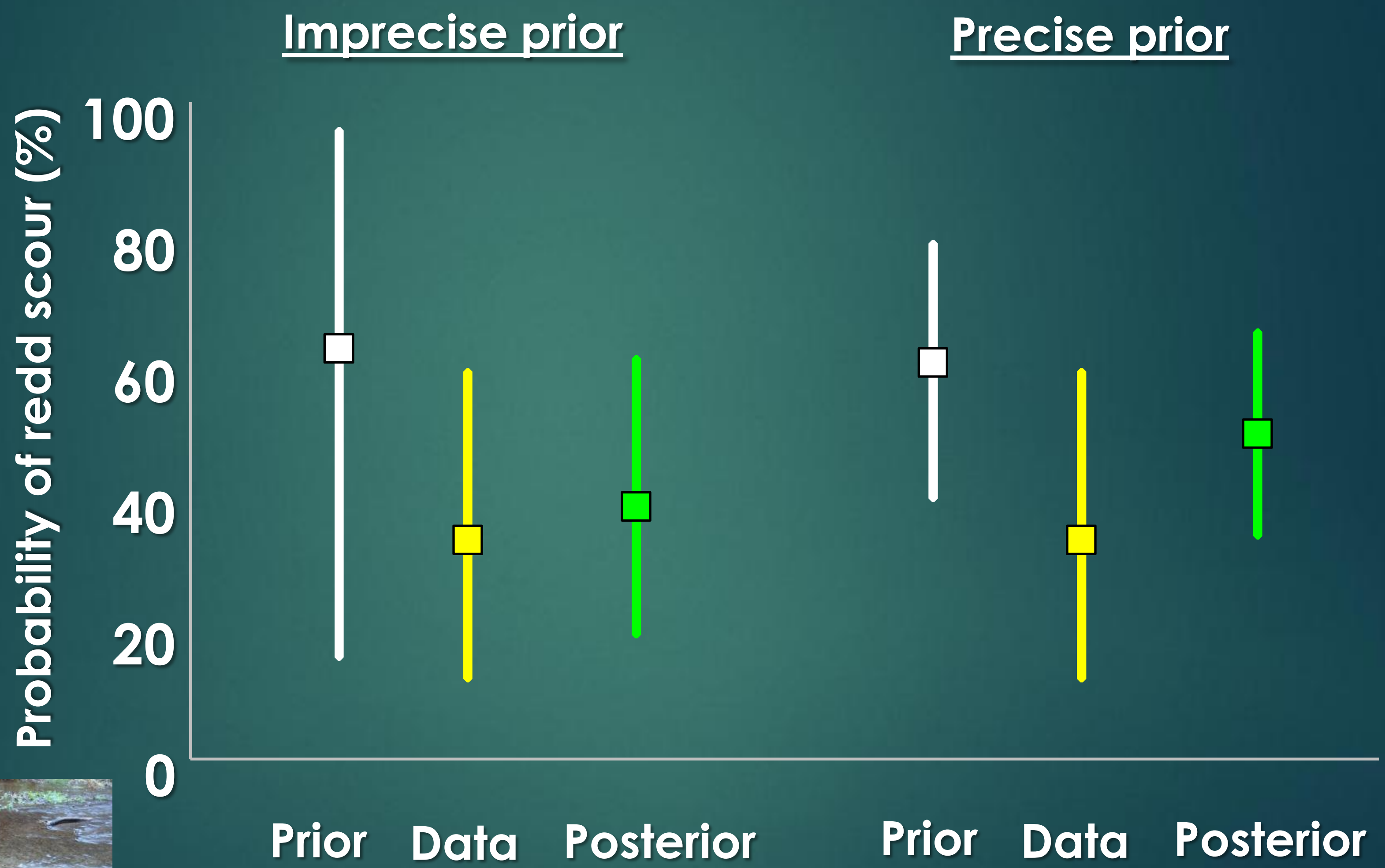


Incorporated into decision modeling using multiple models and model probabilities (weights)

Bayesian inference



Bayesian example



Influence of prior and sample data on posterior

Precision

Prior $\uparrow$, data $\downarrow$, posterior → prior

Prior $\downarrow$, data $\uparrow$, posterior → sample

Sample size

> samples, greater influence

Where do we get priors?

Meta analysis

previous studies

published reports

Expert elicitation

Diffuse (non-informative)

Commonly used tools

Monte Carlo Markov Chain (MCMC)

Integrate multiple data types, sources, and models

Natural fit

Probabilistic networks

Bayesian belief networks

Influence diagrams

Example: Southeast resource assessment

Evaluation of potential climate change effects
- stream flows
- temperature

All habitat and fish population data from southern portion of ACF basin

Very sparse data available for adjacent basins in Blue Ridge

Task: develop models for response of cool water biota

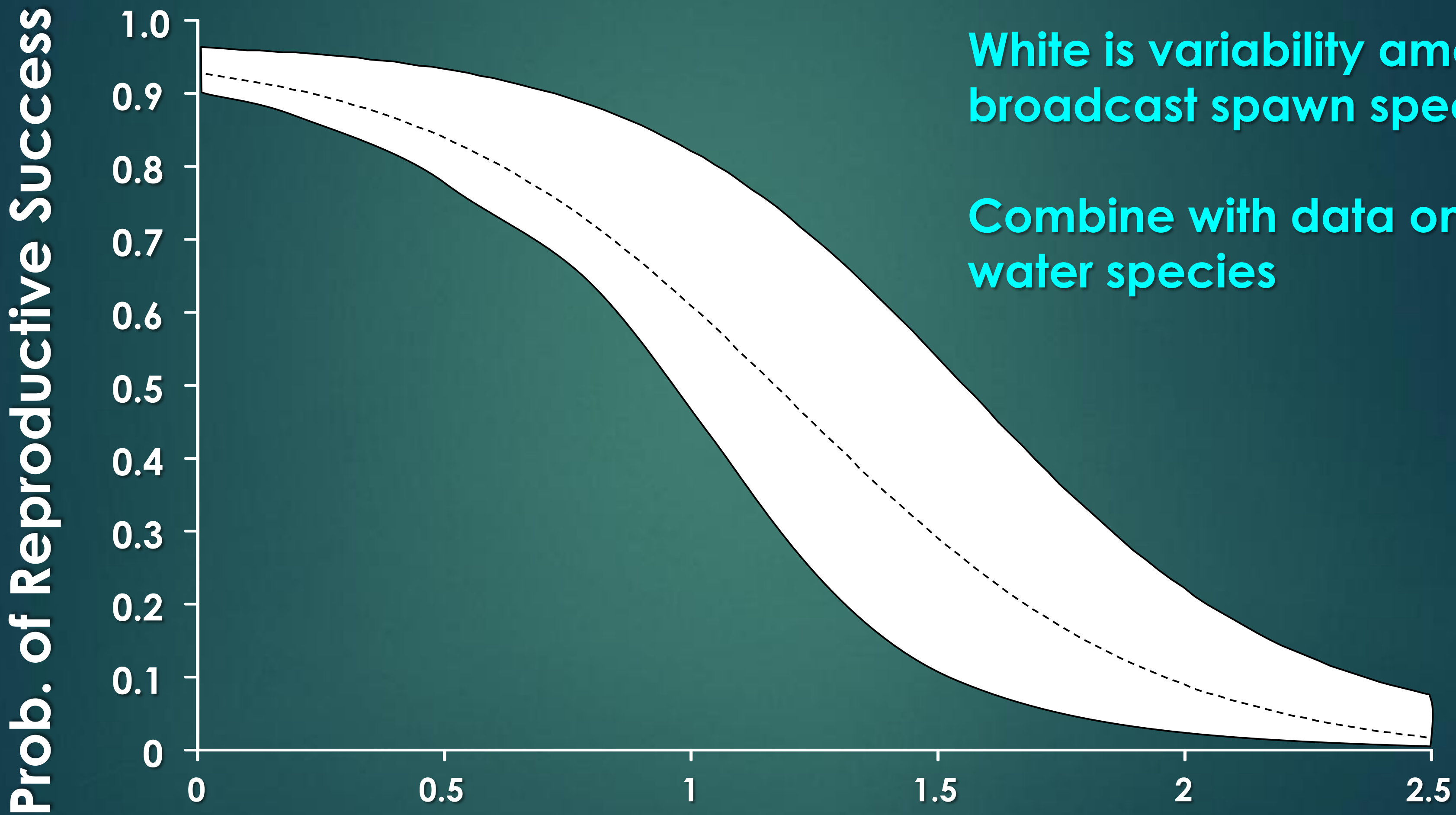
Apalachicola, Chattahoochee, Flint Basin

Existing models of flow-fish relation (the prior)

Trait based

White is variability among broadcast spawn species

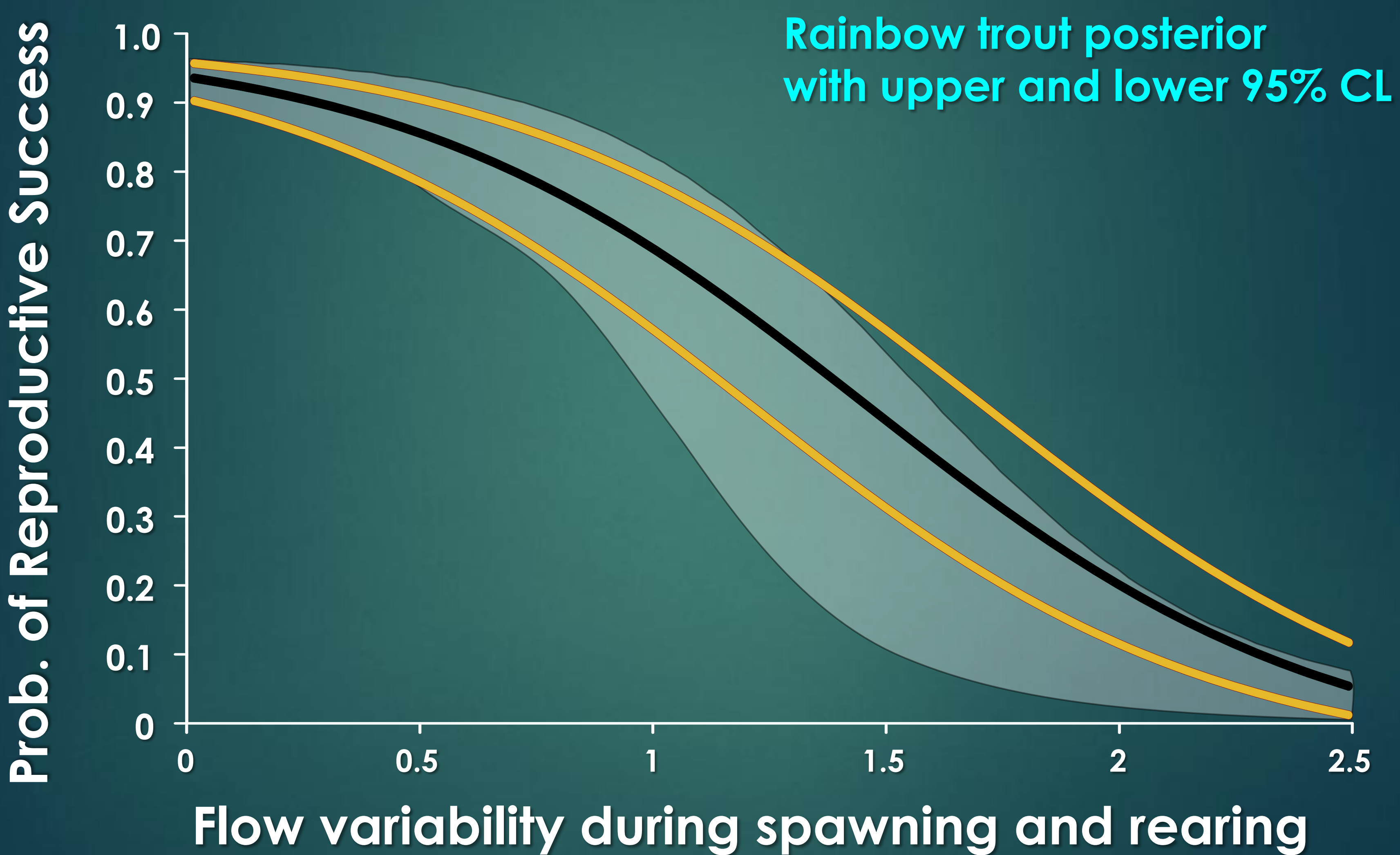
Combine with data on cool water species



Flow variability during spawning and rearing

Peterson and Shea 2014

Existing models of flow-fish relations (the posterior)



Peterson and Freeman

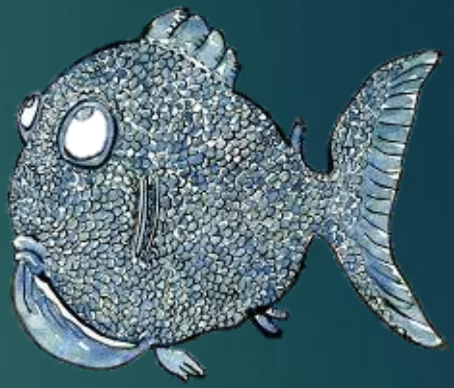
So.. how is this useful for water resource decision-making?

Assuming that we have

- Objectives
- Decision alternatives

Modeling decisions

- Existing models/components
- Meta-analysis
- “Expert” judgment
- Data(?)



Common question:
Won’t the priors affect the model estimates and decision making?

Maybe/probably/yes , but …..

Sensitivity analysis

Identify key uncertainties
sensitivity analysis

Identify the uncertainties affect decisions

- What would we do differently if we knew X?

Prioritize research and monitoring

Focus on decision-making

- What do we need to know?
- How much is enough?

Example: Water availability for ecological needs in the ACF Basin

Spatially explicit

- Stream segment
- Flow, habitat, fish metapopulation models (43 species)

Statistical uncertainty

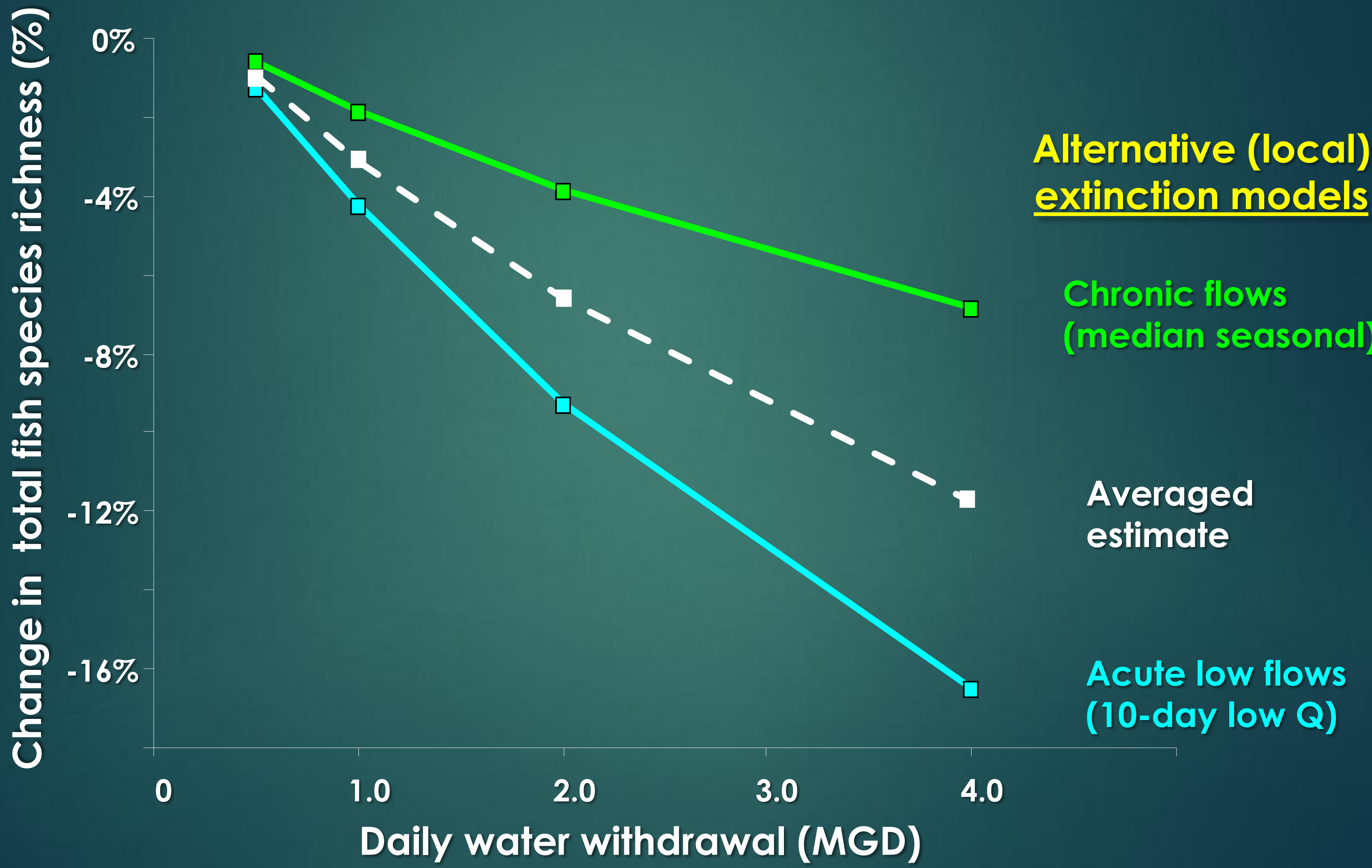
- Flow and habitat model errors

Structural (system) uncertainty

- Alternative fish population demographics models

Freeman et al. 2013

What assumptions/inputs affect the decision?



Reducing Uncertainty

New studies / Experiments

Adaptive management (monitoring)

Prior information

New information (data)

Posterior estimate

Reducing uncertainty

Often want to know…

What will it gain?

How much is needed?

How much is enough?

Value of information

Expected value of decision if no uncertainty

- Model parameters
- Model inputs and system state

Currency that is valued by the decision-makers

- Fish population size
- Water available for use
- Others

Value of perfect information

Example: Alternative extinction hypotheses

Assume constraint: species loss < 5%

System dynamics	Daily water withdrawal (MGD)
Chronic flows	3.50
Acute low flows	1.37
Weighted average	2.44

Composite <u>estimate</u>

1.83 MGD

Value of perfect information: 2.44 – 1.83 = 0.61 MGD

Value of information

But… not all information is perfect (it almost never is)

<u>Some sources of imperfection</u>

Sampling error

Incomplete understanding of process

Random error

Others???

Value of imperfect information

Value of sample information

Multi-species occupancy simulations

2 sample occasions, error (CV) ~ 35%

True richness, given estimated 25: 25 +/- 4

Value of sample information: 0.26 MGD

4 sample occasions, error (CV) ~ 10%

True richness, given estimated 25: 25+/- 2

Value of sample information: 0.49 MGD

Compare to EVPI = 0.61

Reducing uncertainty: monitoring

Spring and summer 2011-2012 (2013)

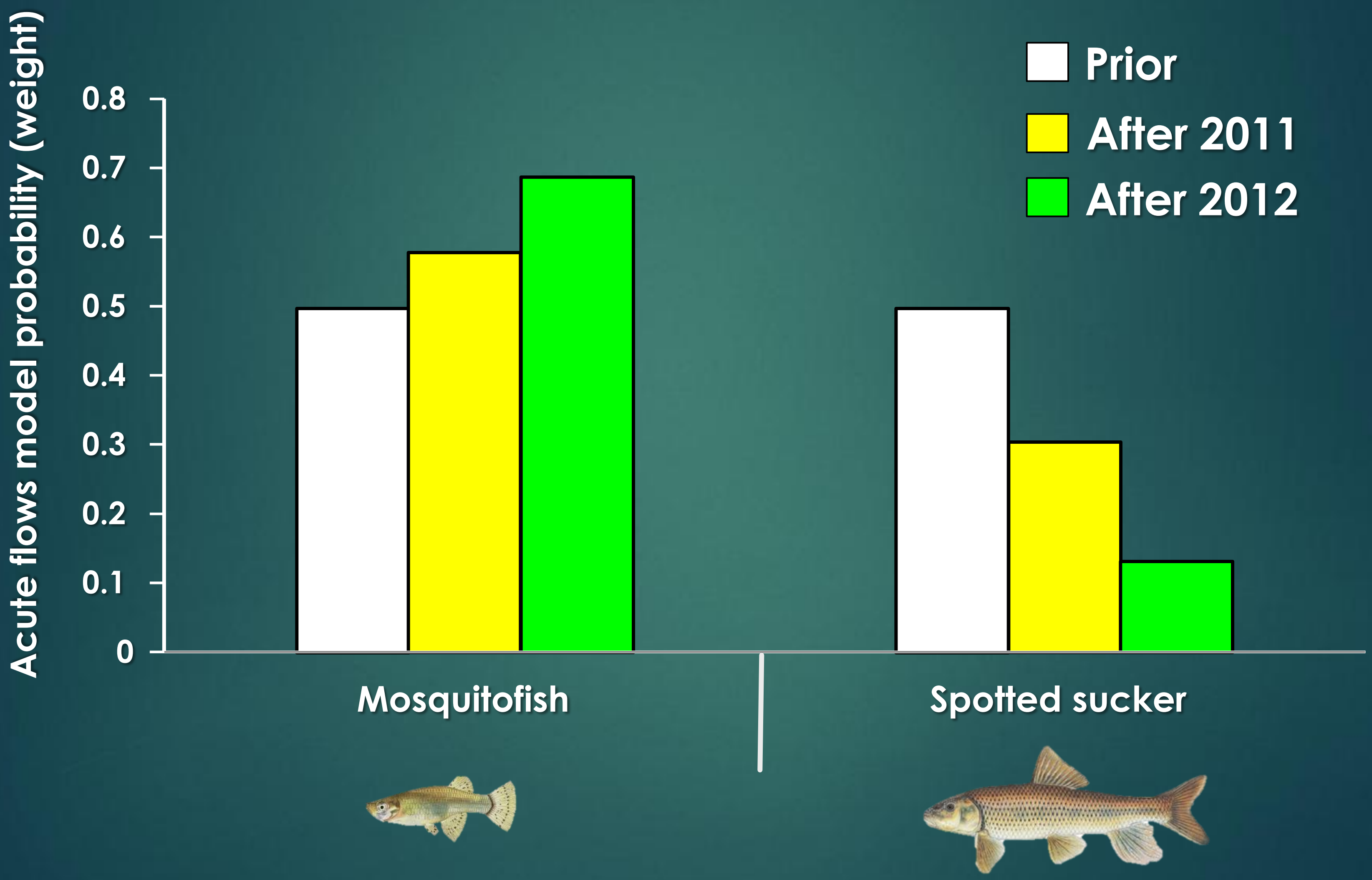
21 sites, 40- 100 m

Electrofishing and seining

Occupancy 2-3 visits season

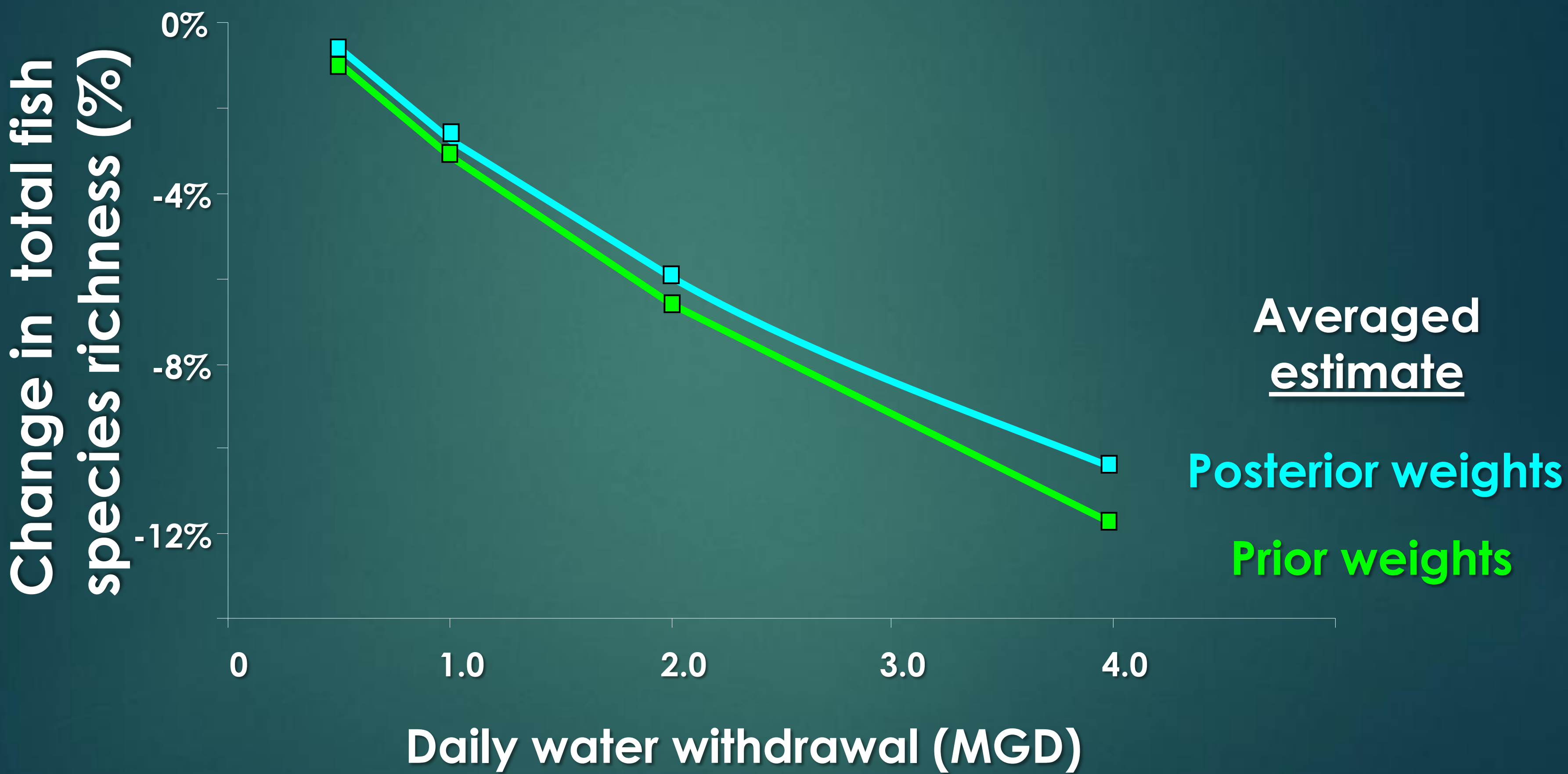
Flint River Basin

Update model probabilities



Peterson and Freeman

Updated estimates of water use effects



Summary

Bayesian approaches

- Underutilized
- Cost/effort savings
- Leverage existing information
- Propagate uncertainty
- Learning through time/space (reduce uncertainty)

Natural fit with decision modeling

- Identify important uncertainties
- Value of (im)perfect information