Decision Making in Wildlife & Fisheries Management

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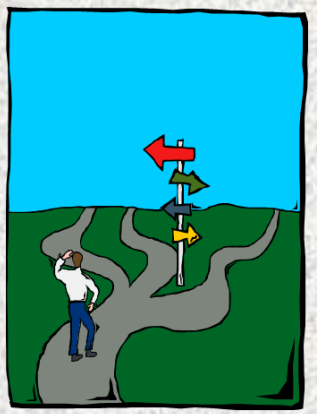
Introduction to Decision Analysis

(Structured Decision Making)



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What is decision analysis?

- The structuring of a decision problem
  - in terms of choices, outcomes, and values
  - to identify the choice that is most likely to meet the objectives
- Decisions involve
  - predicting outcomes from alternative choices
  - valuing those outcomes
- The first part is the (objective) role of science; the second part is the (subjective) role of society

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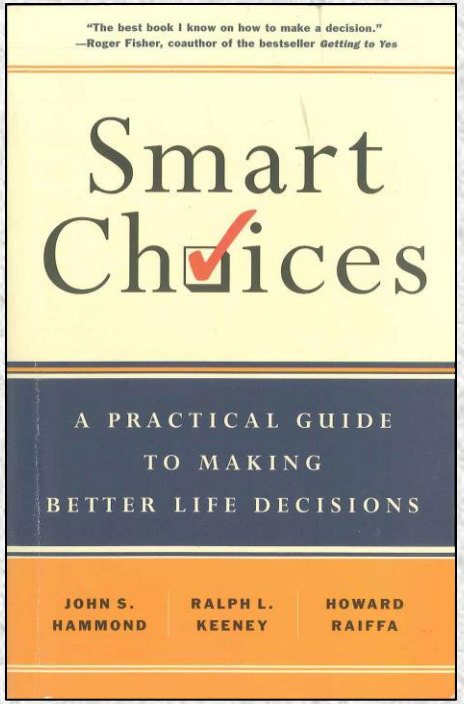
Two Key Aspects

- Problem decomposition
  - Break the problem into components, separating policy from science
  - Complete relevant analyses
  - Recompose the parts to make a decision
- Values-focused
  - Objectives (values) are discussed first, and drive the rest of the analysis
  - In contrast to our intuitive decision-making, which usually jumps to evaluating the alternatives

PrOACT

- Problem framing
- Objectives
- Actions
- Consequences (models)
- Trade-offs

Hammond, J. S., R. L. Keeney, and H. Raiffa. 1999. Smart Choices: A Practical Guide to Making Better Life Decisions. Broadway Books, New York, N.Y.



Problem framing

- What triggered the need for a decision?
- What is the nature of the decision (choices)?
- Who is (are) the decision maker(s)?
- What are the legal context and constraints?
- Class of problem?
  - objectives: single or multiple objective
  - temporal & spatial scale (grain & extent)
  - role of uncertainty

Objectives

- Explicit statement allows focused discussion, negotiation, and evaluation
- Explicit & quantifiable measures for evaluating choices
- E.g., maximize cumulative harvest over a long time horizon, maximize the probability of species persistence, minimize occupancy rate of an invasive for a fixed budget

Potential actions

- Sometimes the list of potential actions is clear
  - But often, generating such a list is a challenge
  - Often the range of options initially discussed is unnecessarily narrow
- How can the objectives be achieved?
  - Develop creative & unique alternatives before assessing feasibility and efficacy
  - Don’t anchor on the initial set of options
  - Challenge apparent constraints
- Objectives should be sufficient to evaluate all of the alternatives
- Alternatives should include all the ways the objectives could be achieved


M - PULSE II

Consequences

…decision making is a forward-looking process…. And if decision making is the attempt to achieve a desired future, then any such attempt must include, implicitly or explicitly, a vision of what that future will look like.

Sarewitz et al. (2000). Prediction: Science, Decision Making, and the Future of Nature. Island Press.

Prediction is very difficult, especially about the future.

Niels Bohr, Danish physicist (1885 – 1962)

Predicting Consequences (modeling)

- Models predict consequences of alternative actions, in terms that are relevant to the objective(s)
- The decision context must guide model development (not the other way around)
- Models come in an array of shapes & sizes

Trade-offs and Optimization

- Trade-offs exist when no single action is expected to perform the best on all objectives
- Choosing the best action (optimization) involves deciding the relative importance of the multiple objectives
- Balancing trade-offs can be more difficult than identifying the objectives themselves

Rolling Thunder Prairie example

- Problem bounding and formulation
- Objectives
- Alternatives
- Consequences
- Tradeoffs

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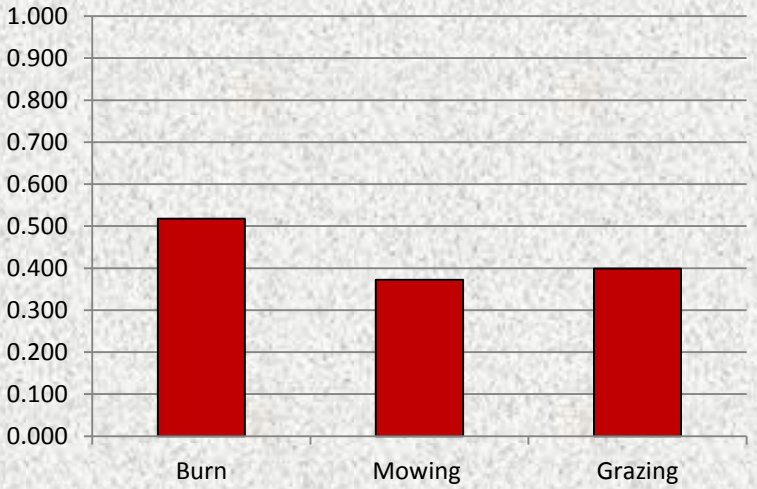
PrOACT

- Problem: Critical habitat for listed orchid; early-succession habitat required; how to prevent woody plant encroachment? one-off decision (can be revisited) within bounds of state preserve; decision maker is preserve manager; minimal uncertainty
- Objectives: orchids, biodiversity (most important); cost, neighbor relations (less important)
- Actions: mow, burn, graze
- Consequences: mix of empirical data & professional judgment
- Tradeoffs: choose action with highest weighted average of benefits

Rolling Thunder Prairie

		Treatment (Alternatives)		
Objectives	**Weight**	**Burn**	**Mowing**	**Grazing**
Cost	0.05	0.018	0.000	0.050
Neighbor Complaints	0.05	0.000	0.050	0.040
Effects on Listed Plants	0.50	0.500	0.056	0.000
Effects on Butterflies	0.20	0.000	0.067	0.200
Effects on Beetles	0.20	0.000	0.200	0.109
Final Score (sum of weighted scores/sum of weights)		**0.518**	**0.372**	**0.399**



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Benefits of SDM

- Decision processes that are
  - Transparent & explicit
  - Deliberative
  - Rational
  - Reproducible
- Good decisions don't guarantee a good outcome (but should perform better on average than intuition)

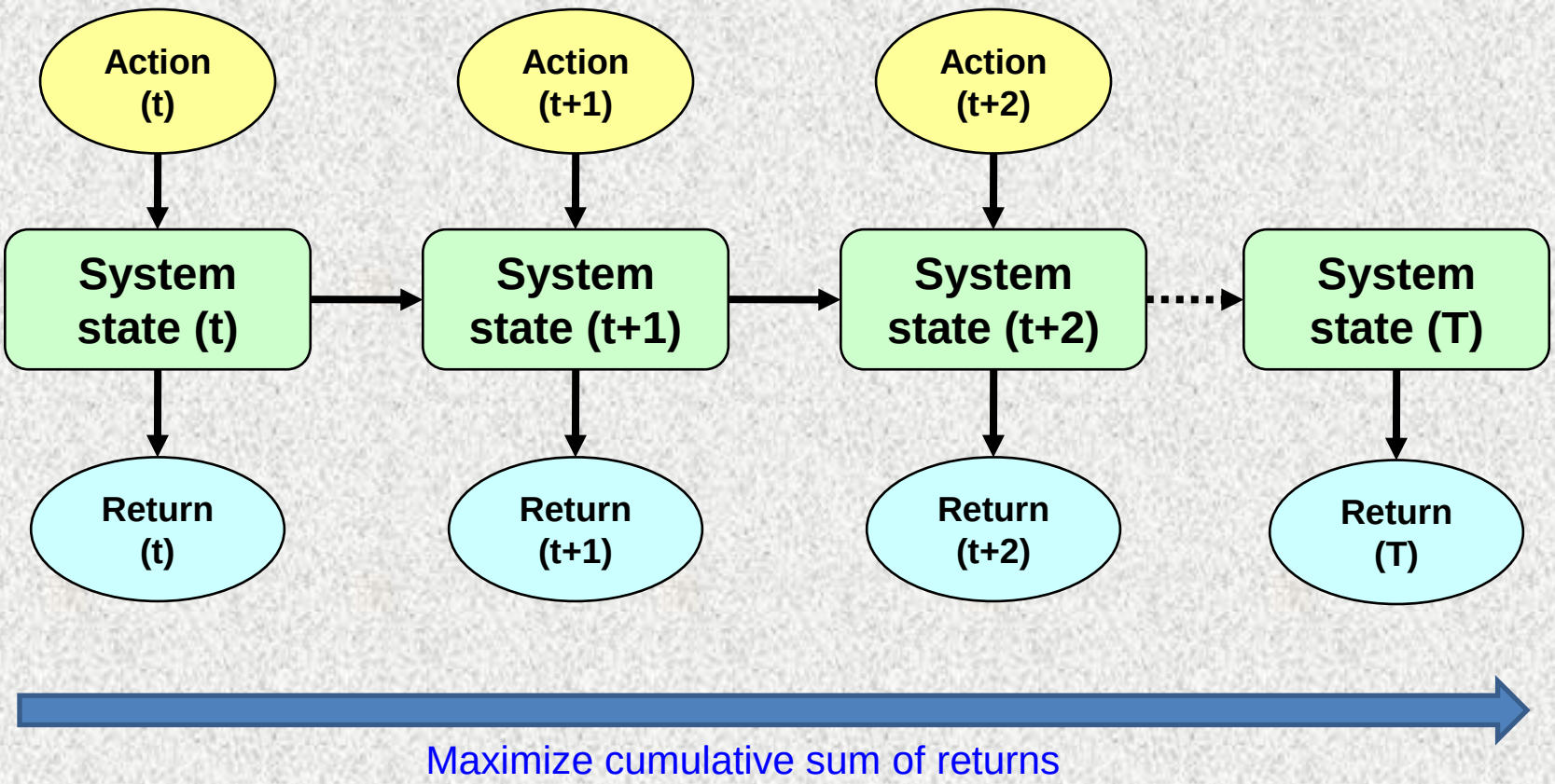
Introduction to Adaptive Resource Management

Essential features of AM problems

- Decisions must be *dynamic* (repeated over time)
- There must be *uncertainty* as to the impacts of management (*and* the uncertainty must matter)
- Management actions must be *differentially informative*
- Monitoring can be used to *compare* predictions and realized management responses

Dynamic decisions

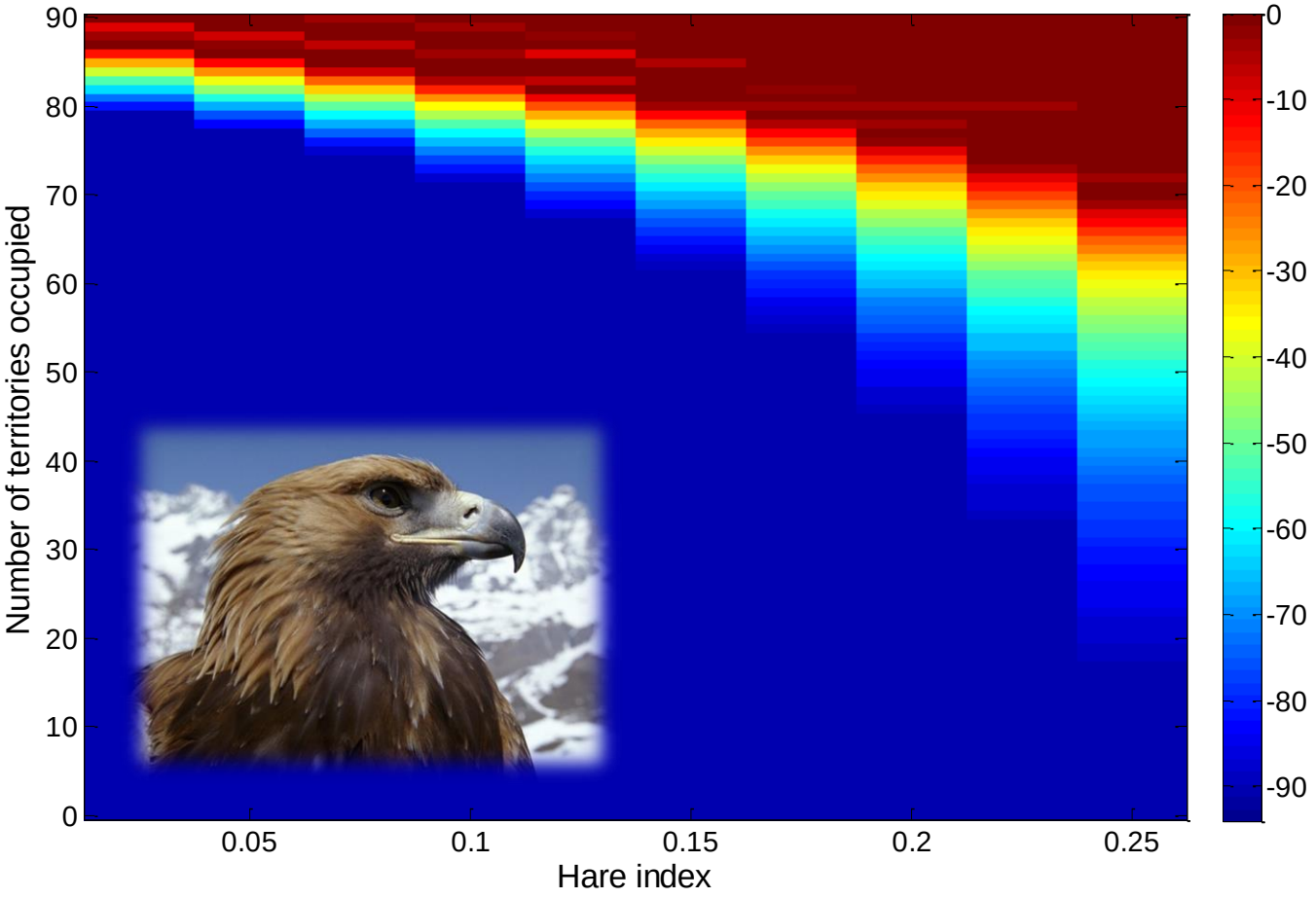
- Many decision-problems are recurrent; e.g., prescribed burning, harvesting, impoundment management, pest control, stocking/translocation, allocation of funds
- Decisions today have both immediate and long-term consequences;
- Key question: how to balance short and long-term gains to do well over the entire time frame?


Action (t)
Action (t+1)
Action (t+2)
System state (t)
System state (t+1)
System state (t+2)
System state (T)
Return (t)
Return (t+1)
Return (t+2)
Return (T)
Maximize cumulative sum of returns

Solutions to dynamic decisions:

- Provide a management policy or strategy that prescribes the optimal action for each possible state of the system at each time step
- Balance short-term and future returns to provide maximum management performance over the time frame (decisions are forward-looking)
- *Optimal* solutions have a “closed-loop” or “feedback” property, meaning that it doesn’t matter if the future unfolds differently than you expected

Managing golden eagle disturbance



Martin et al. 2011. An adaptive-management framework for optimal control of hiking near golden eagle nests in Denali National Park. Conservation Biology.

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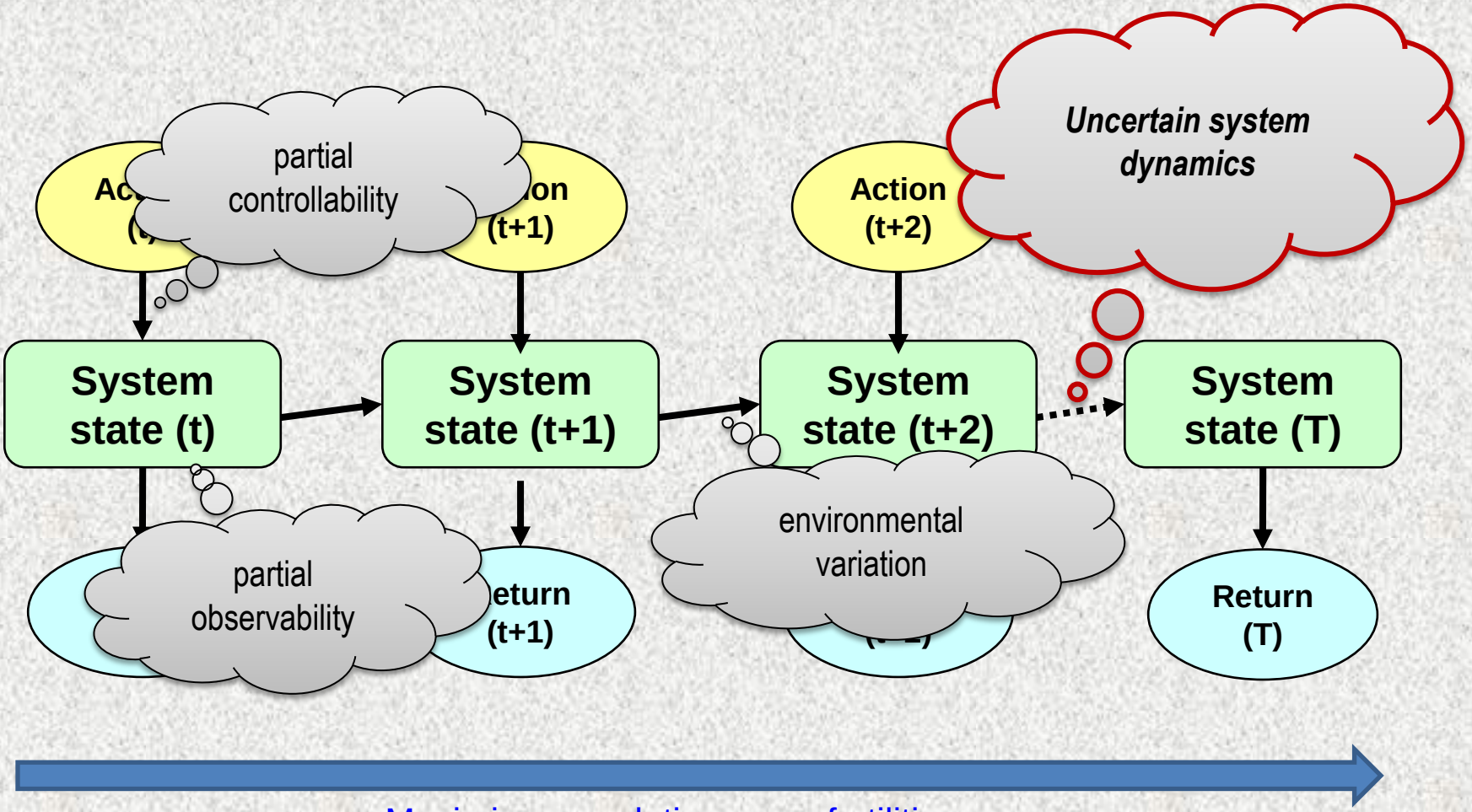
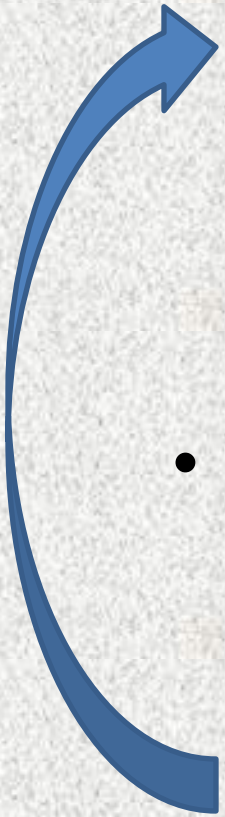
Sources of uncertainty



Adaptive Management



Choose an action based on:

- Management objectives
- Current model weights
- Current system state

- Each model predicts a different system response, and these are compared with the observed response

Update model weights

Adaptive Harvest Management

- Objective: maximize long-term cumulative (i.e., sustainable) harvest of mallards, subject to a constraint on minimum population size
- Actions: Closed, Restrictive, Moderate, or Liberal hunting regulations
- Consequences: based on 4 alternative models (2 survival and 2 reproductive hypotheses)
- Process: optimize, learn, adapt, repeat

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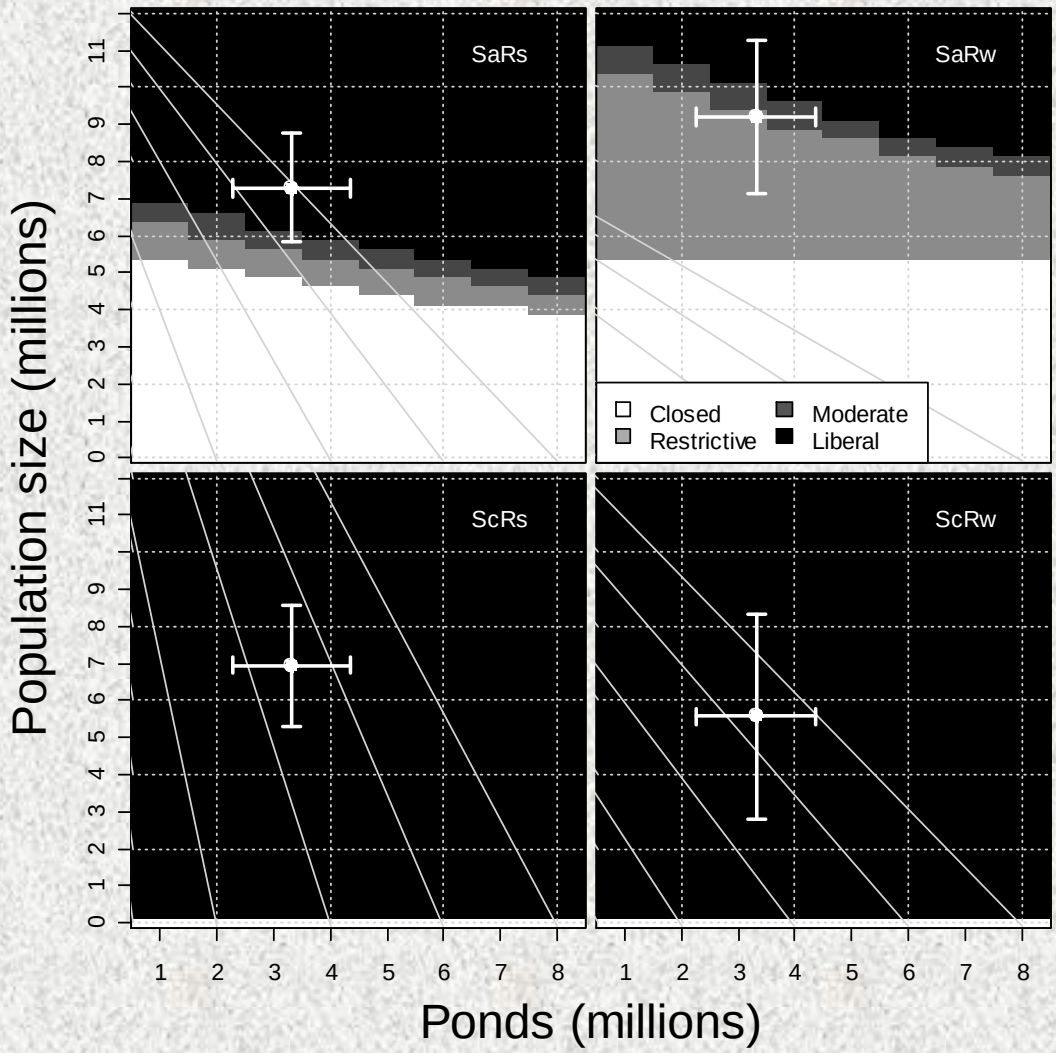
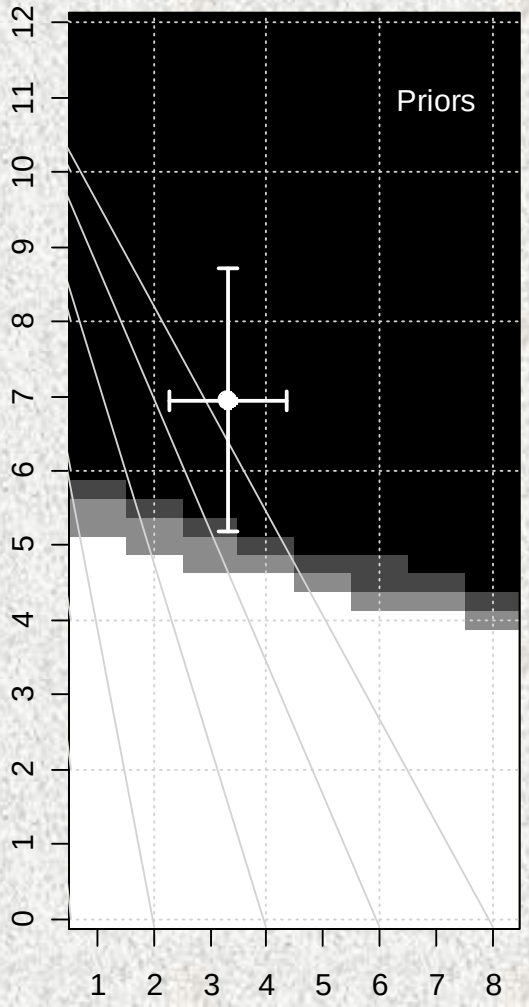
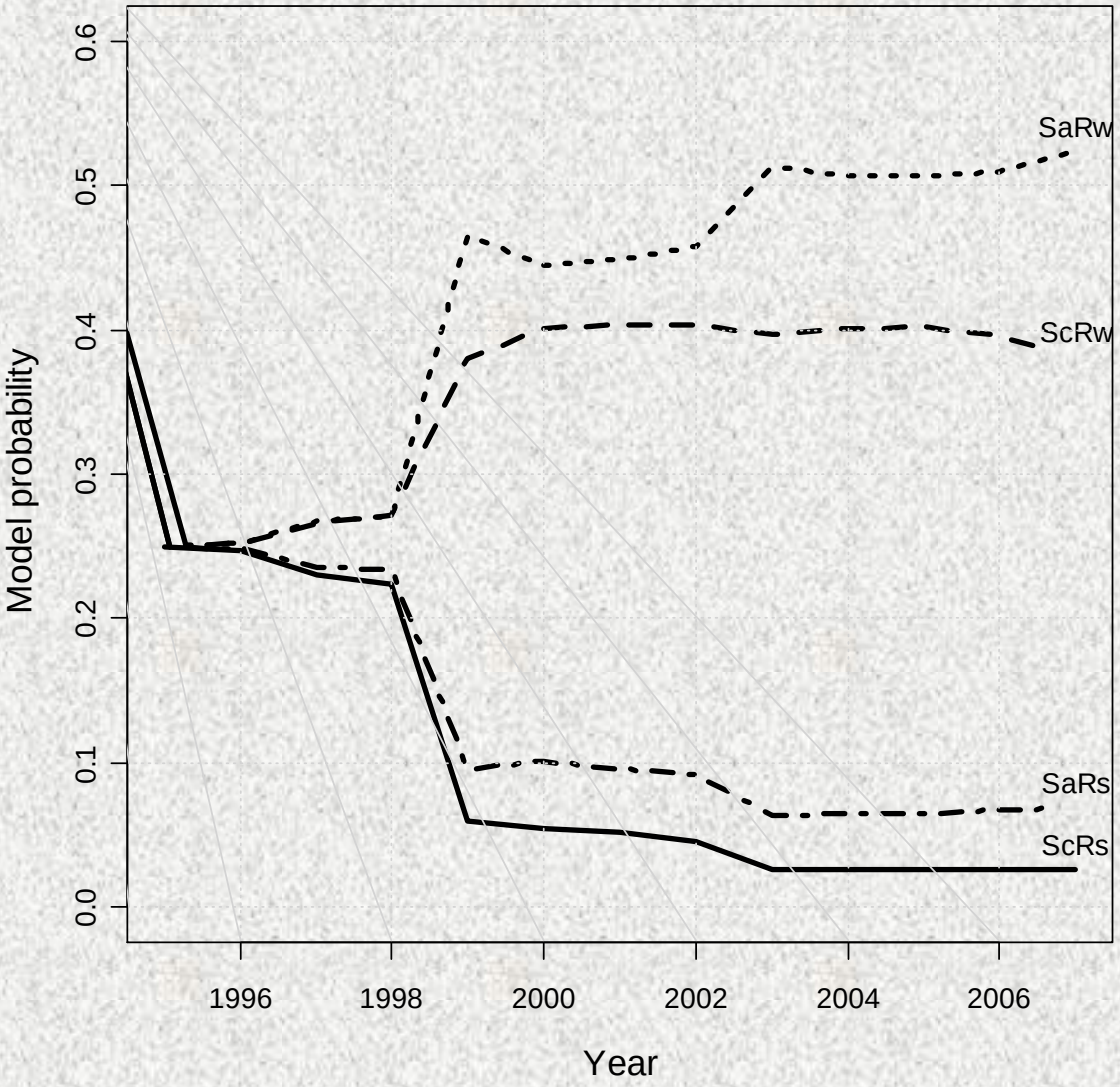
Optimizing

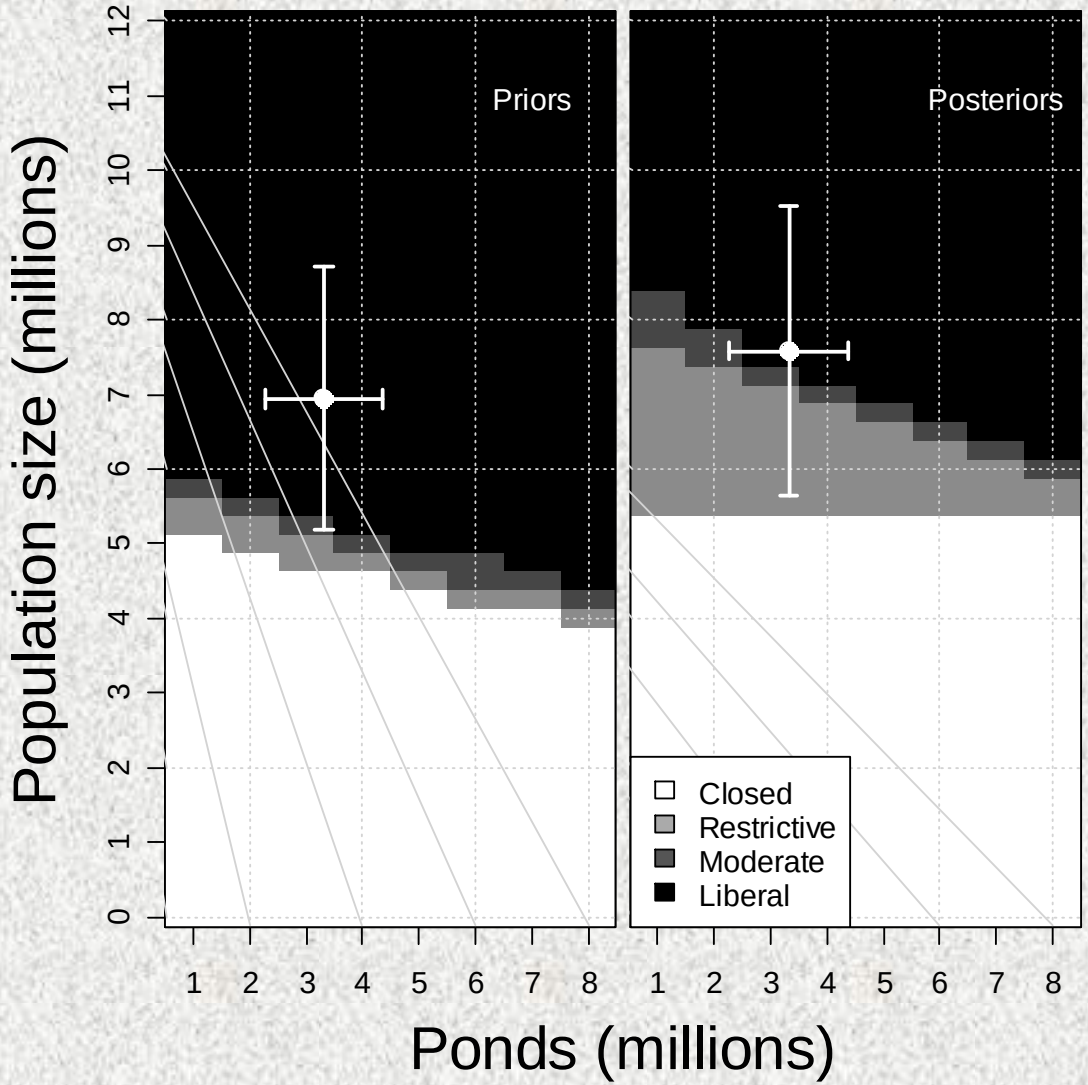

SaRs
SaRw
ScRs
ScRw
Closed
Restrictive
Moderate
Liberal
Population size (millions)
Ponds (millions)


Priors

Learning


Model probability
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1996
1998
2000
2002
2004
2006
Year
SaRw
ScRw
SaRs
ScRs

Adapting

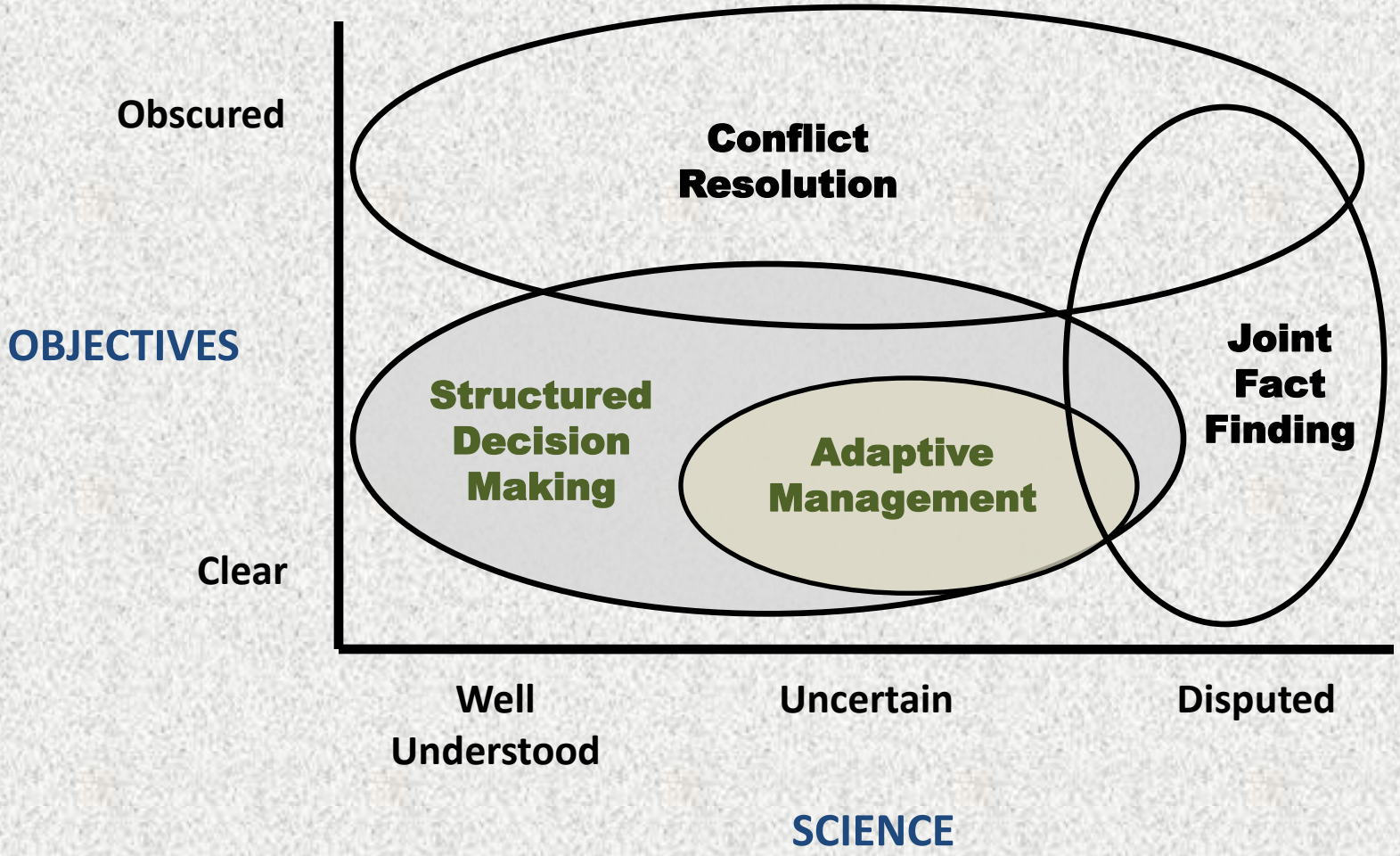

Priors
Posteriors
Population size (millions)
0
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
Ponds (millions)
Closed
Restrictive
Moderate
Liberal

Forms of adaptive management

- ***Passive*** (learning a unplanned by-product)
  - Use best system model to make decision; then refine model through monitoring of outcomes
  - Use model averaging to make decisions; then update model weights based on a comparison of predicted & observed outcomes

- ***Active*** (taking informative mgmt actions)
  - Learn then do: set up experiment to reduce uncertainty; then modify mgmt based on what is learned (suboptimal)
  - Learn while doing (the problem of "dual control"): occasional probing of the system, with intent to balance need to learn with desire for maximum mgmt performance (optimal)

SDM & AM in larger context



What to remember from today:

- Decision analysis is the structuring of a decision problem in terms of choices, outcomes, and values
- Outcomes are the purview of science; choices and values are the purview of management
- PrOACT steps for analyzing a decision
- Adaptive management is decision analysis
  - for dynamic problems with uncertain consequences
  - where actions are differentially informative
  - and where learning is based on monitoring of outcomes