Recurrent Decisions & Adaptive Management

Chapter 2

Developed by: James D. Nichols, Michael C. Runge, Fred A. Johnson

<u>Session Objective:</u> **By the end of this session, participants will be able to:**

- Discuss what makes recurrent decisions different from as they relate to adaptive management.

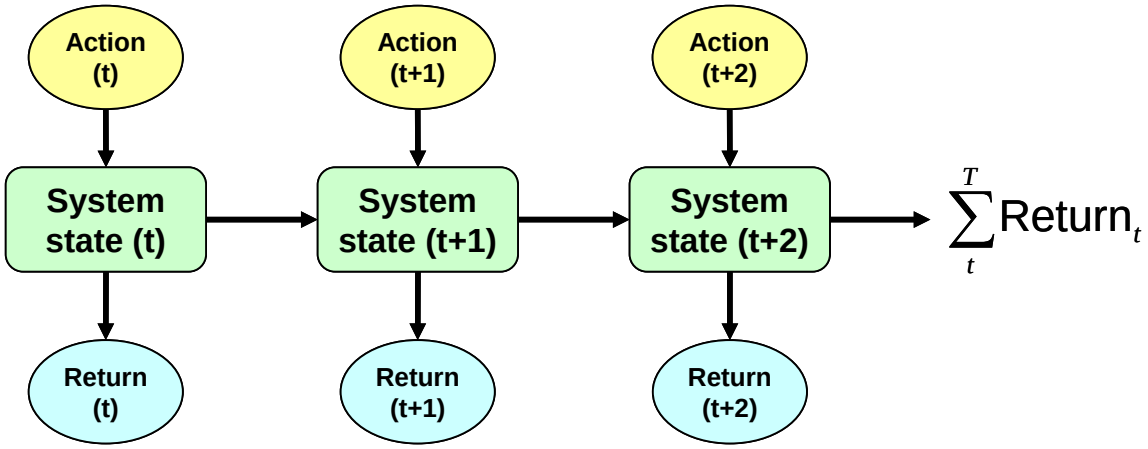
Recurrent Decisions

- Some decisions are repeated over time, at regular (or irregular) intervals
- What makes recurrent decisions different?

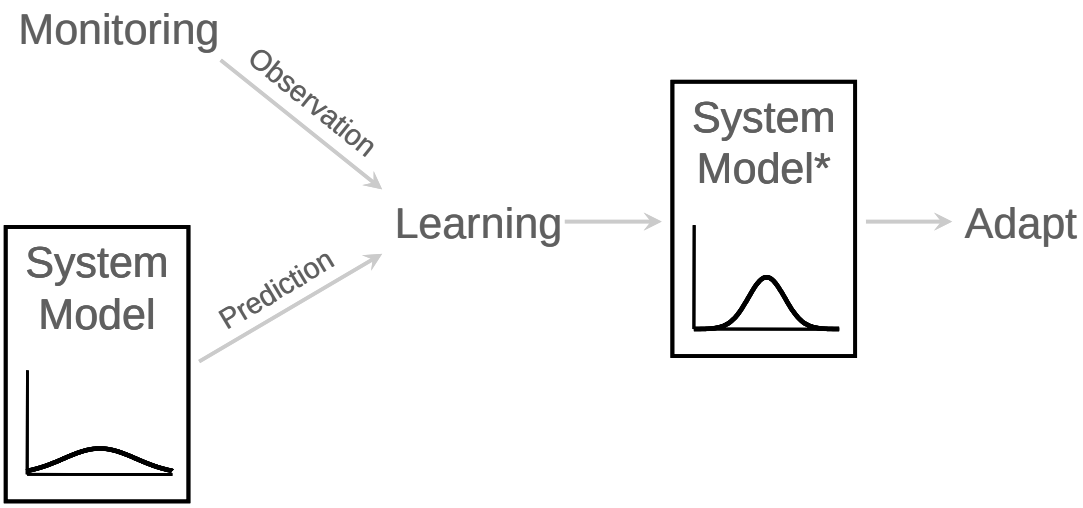
Recurrent Decisions: What's Different?

- Added complexity
  - Current decisions influence future state(s) and, therefore, future actions
- Opportunity to learn
  - Comparison of model-based predictions with monitoring data permit learning

Dynamic



Adaptive



Structured Decision Making (SDM) for Recurrent Decisions

- How do the elements of SDM need to be thought of for recurrent decisions?
  - Objectives
  - Actions
  - Models
  - Monitoring & Learning
  - Optimization

Objectives & Actions

Objectives

- As in SDM, objectives retain their primacy
  - Objectives drive the development of other aspects of the Adaptive Resource Management (ARM) framework

- For decisions by public agencies, there may be significant input from stakeholders in setting objectives
  - A careful process for developing these objectives is often needed
  - Balance regulatory responsibilities of agencies (legislative mandate) with current input from stakeholders

Dynamic objectives

- For recurrent decisions, the objectives may need to reflect the accrual of benefits and costs over time
  - This can be explicit, e.g., $\max \sum_{t=0}^{T} H_t$
  - Or implicit, e.g., $\min p\left(E_{100}\right)$

Actions

- For recurrent decisions, some consideration needs to be given to how the set of alternative actions may change over time

- Several scenarios
  - Fixed set of alternatives
  - Time-dependent set of alternatives
  - Dynamic set of alternatives (known dynamics)
    - i.e., decision today affects options tomorrow, in known way
  - Developing an adaptive set of alternatives

Evolution of Objectives and Available Actions

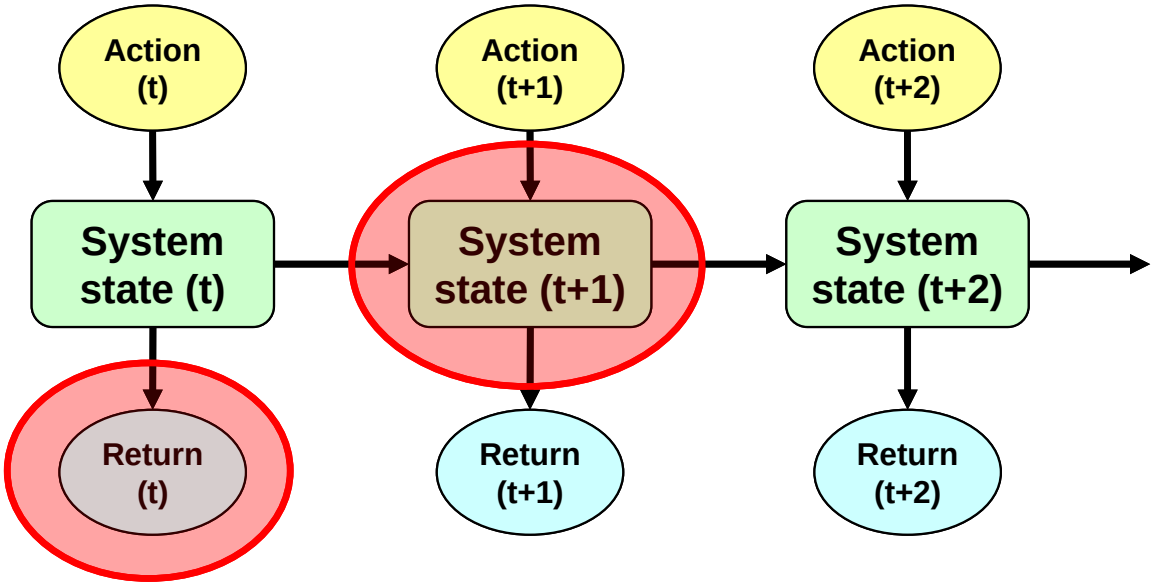
- "Double-loop learning"
  - Experience with process and/or changes in stakeholder attitudes may make it useful to revisit objectives
  - Alternative management actions may evolve as initial actions demonstrate limited effectiveness or as the problem is re-framed

Models

Models for Recurrent Decisions

- Primary use: dynamic predictions
  - What is the expected current return (value) of a particular action?
  - How will the resource conditions change as a result of an action? (Hence, how will future returns change?)

Dynamic Models



Shorebird Use of Wetlands

- Predict current use of impounded wetland, as a function of
  - Action taken
  - Current vegetation state

- Predict next year's vegetation state, as a function of
  - Action taken

But, we acknowledge uncertainty

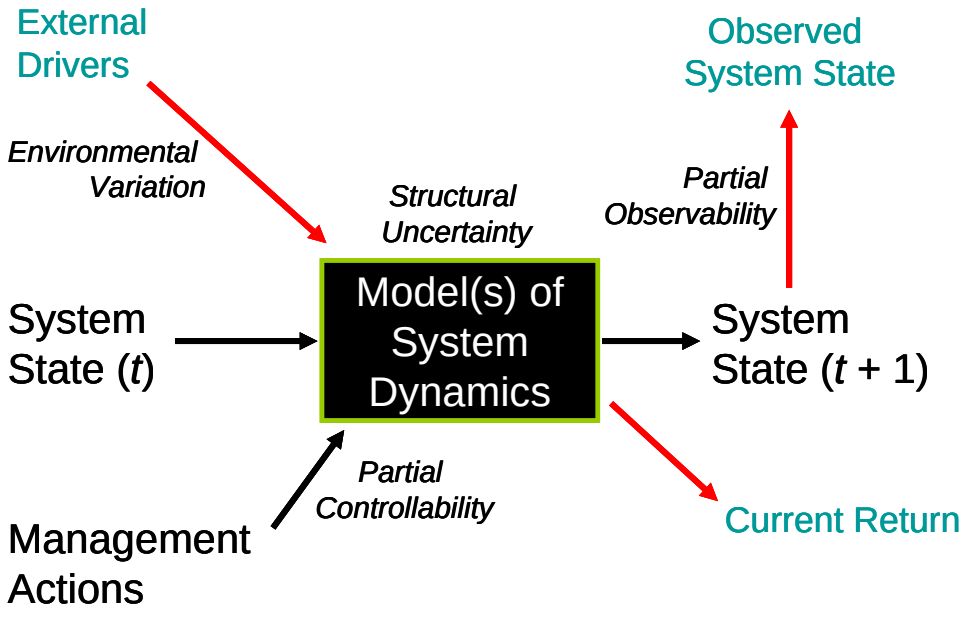
Forms of Uncertainty Incorporated in Models

- Environmental variation

- Partial controllability

- Partial observability

- Structural uncertainty
  - a form of epistemic uncertainty about the effects of management actions
  - a focus of adaptive management

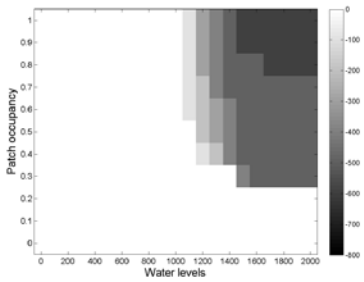


Model Uncertainty

- Ecological (structural) uncertainty
  - Nature of system dynamics is not completely known
  - Competing ideas about system response to management actions

- The focus needs to be on uncertainty about the effects of alternative actions
  - Uncertainty that matters to your ability to achieve your objectives

T = 1500



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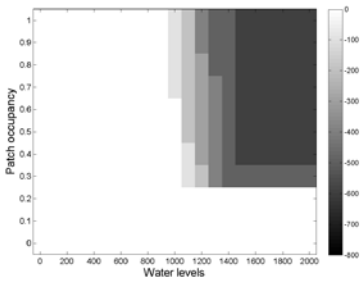
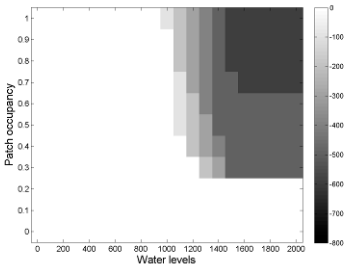


Equal Model Weights



Monitoring & Learning

Monitoring

- Purposes
  - To assess the state of the system for the purpose of making state-dependent decisions
  - To determine if the objectives are being met
  - To resolve uncertainty (learn)

- The development of the monitoring system should be tailored to these needs & driven by the decision context

Learning

- Learning
  - Resolution of structural uncertainty over time

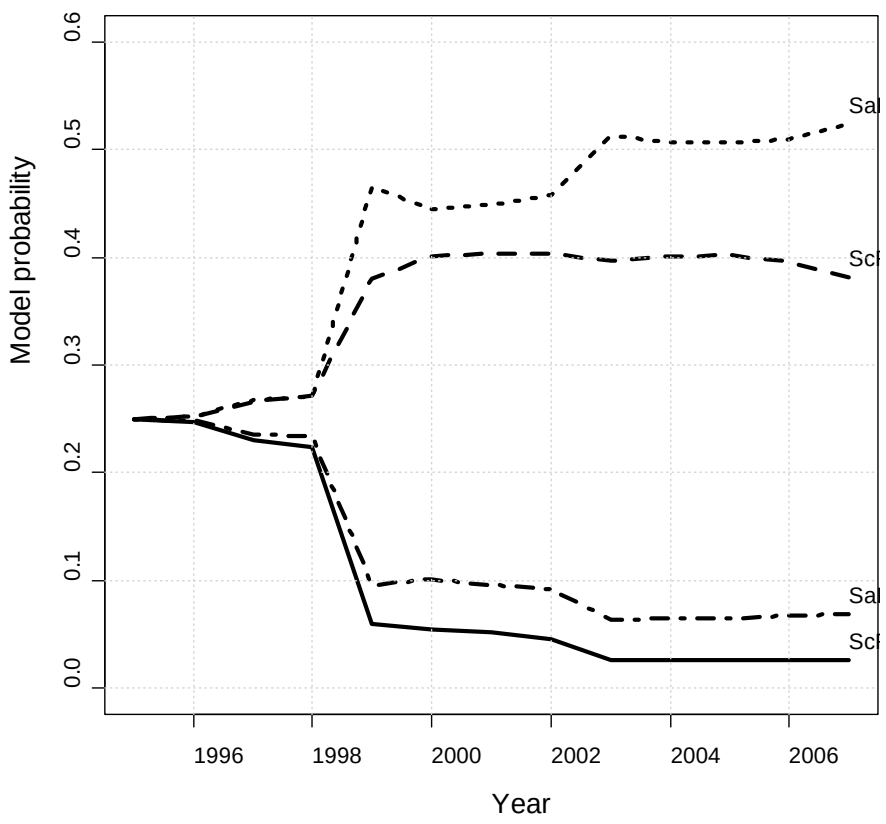
- In a management setting
  - Learning is not the ultimate goal, although it might be a proximate goal
  - How will learning be applied to subsequent decisions?

- In essence, the way to grapple with uncertainty:
  - Make short-term predictions and ask how well they match observed (via monitoring) dynamics (science)
  - But have a clear plan for how learning will change future decisions

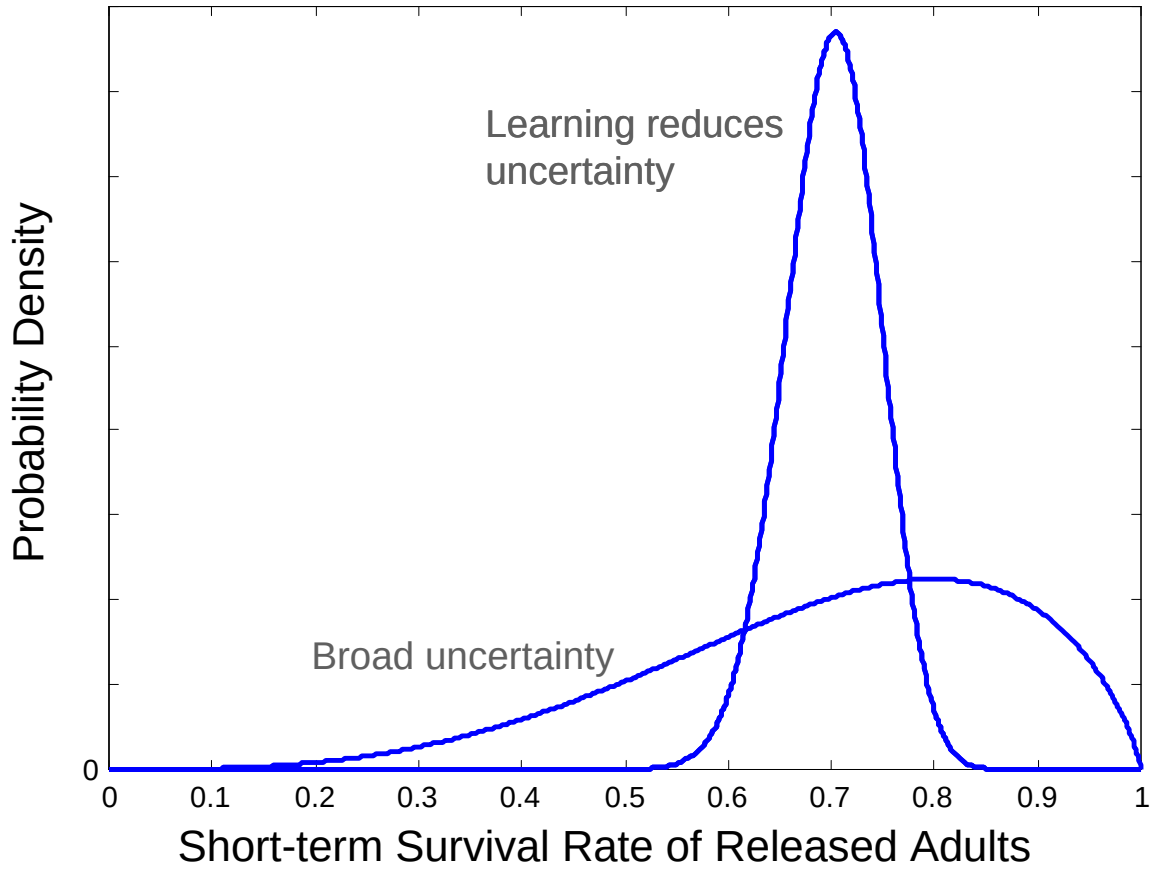
Model Weights

- Often, we can express structural uncertainty with a discrete set of alternative models
- Weights associated with those models reflect relative degrees of faith
- Updating model weights
  - Each model makes a prediction
  - Comparison of those predictions to the observed result (monitoring) allows updating
  - Bayes Theorem used to update based on:
    - Previous weights
    - Comparison (prediction versus monitoring)

Adaptive Harvest Management



Continuous Set of Models



Optimization

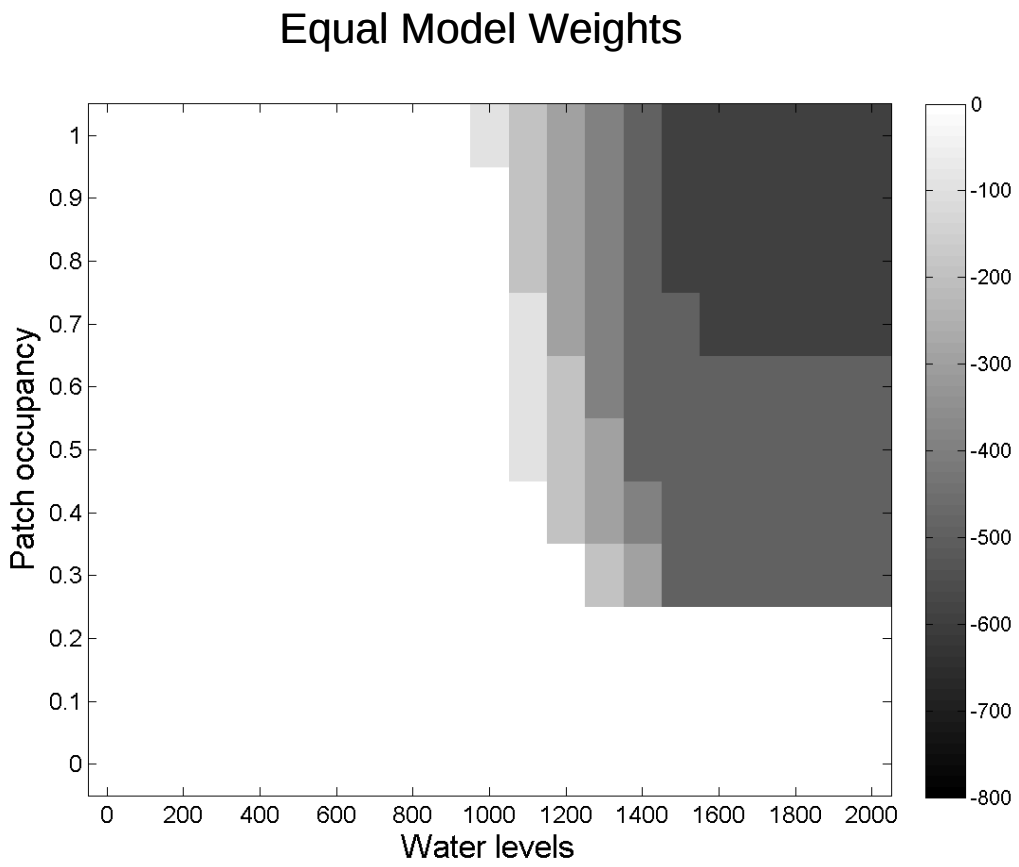
Optimization

- Any informed decision entails a comparison of predicted outcomes of applying the potential actions (which action is "best", with respect to the objectives)

- As in SDM, the role of optimization is to find the action that best achieves the objectives, given the predictions from the model(s)

- For recurrent decisions, the optimization may need to be
  - Dynamic
  - Adaptive

Dynamic Optimization



Adaptive Optimization

- Actions have the potential to reduce uncertainty
  - Perhaps not equally

- Thus, we need to also anticipate how uncertainty will change over time, and how that will affect future decisions

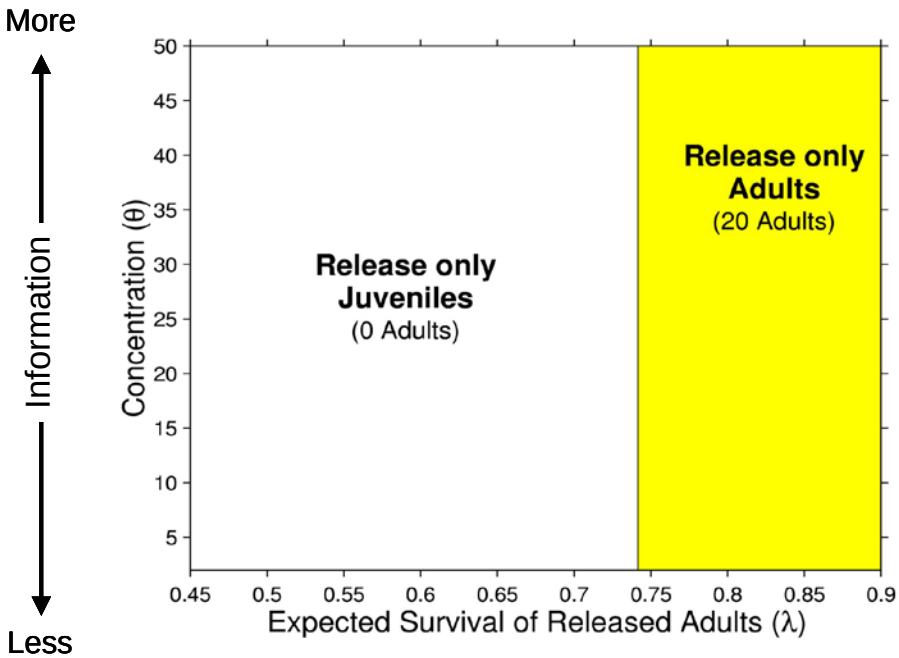
- Adaptive optimization deals with the "Dual Control Problem", balancing
  - The short-term costs of learning, with the
  - Long-term benefits of learning (are "probing" actions warranted?)

- So-called "active" adaptive management

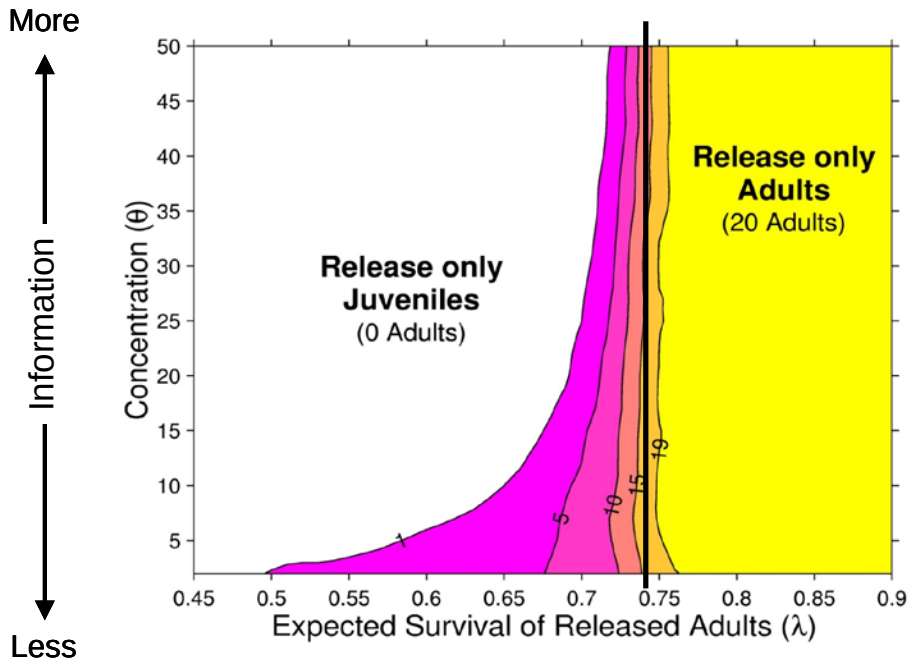
- Approaches to adaptive optimization
  - Discrete model set: carry information state (vector of model weights) as a state variable
  - Models characterized by key parameter of general model: parameter value and variance are relevant

Reintroduction of Griffon Vultures

Non-adaptive solution



Adaptive solution



Putting it all Together

Motivation

- All management decisions are made without perfect knowledge
- This uncertainty makes decisions difficult
- Any management decision can potentially provide the chance to learn
- Iterated decisions can be adaptive

Adaptive Management

Seeks to optimize management decisions in the face of uncertainty,
using learning at one stage to influence decisions at subsequent stages,
while considering the anticipated learning in the optimization.

Adaptive Management or Structured Decision Making?

- Is the decision recurrent?
- Is there structural uncertainty that matters in terms of management decisions? (do we need to learn?)
- Is there a monitoring program that is sufficiently focused and precise to discriminate among alternative hypotheses / models? (can we learn?)
- Is there an ability to change management strategy in response to what is learned? (can we adapt?)
- If “yes” to all, then AM

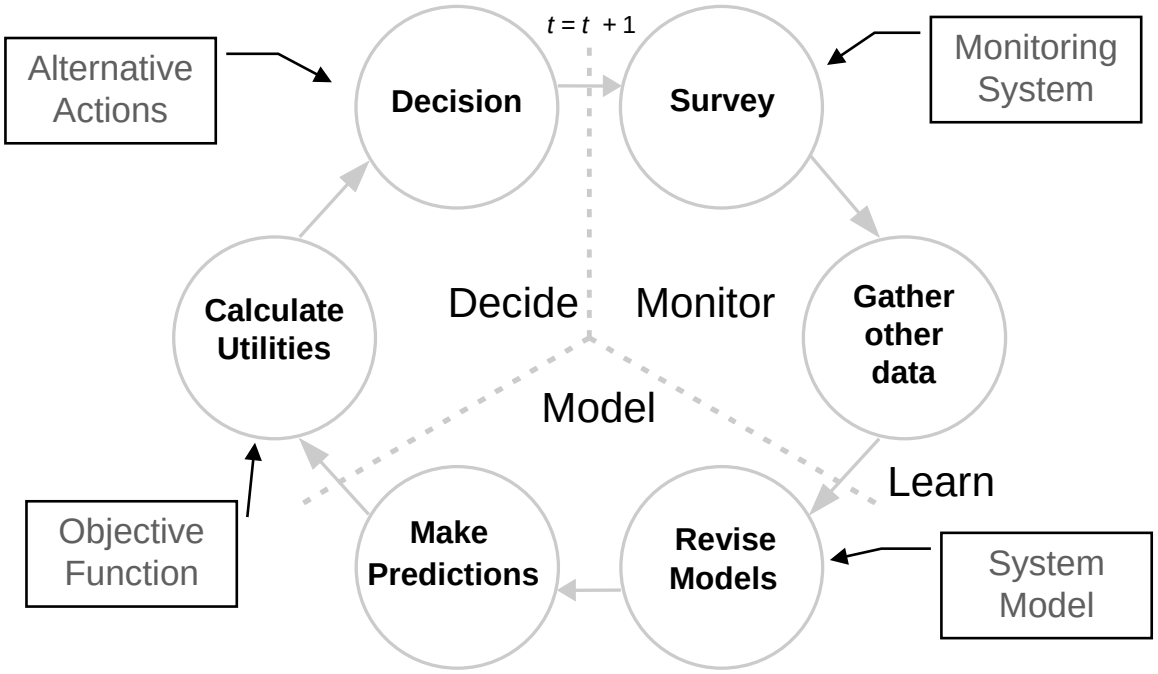
Adaptive Management: Process

- Use dynamic optimization to select management action based on:
  (1) objectives
  (2) available management actions
  (3) estimated state of system
  (4) models and their measures of credibility

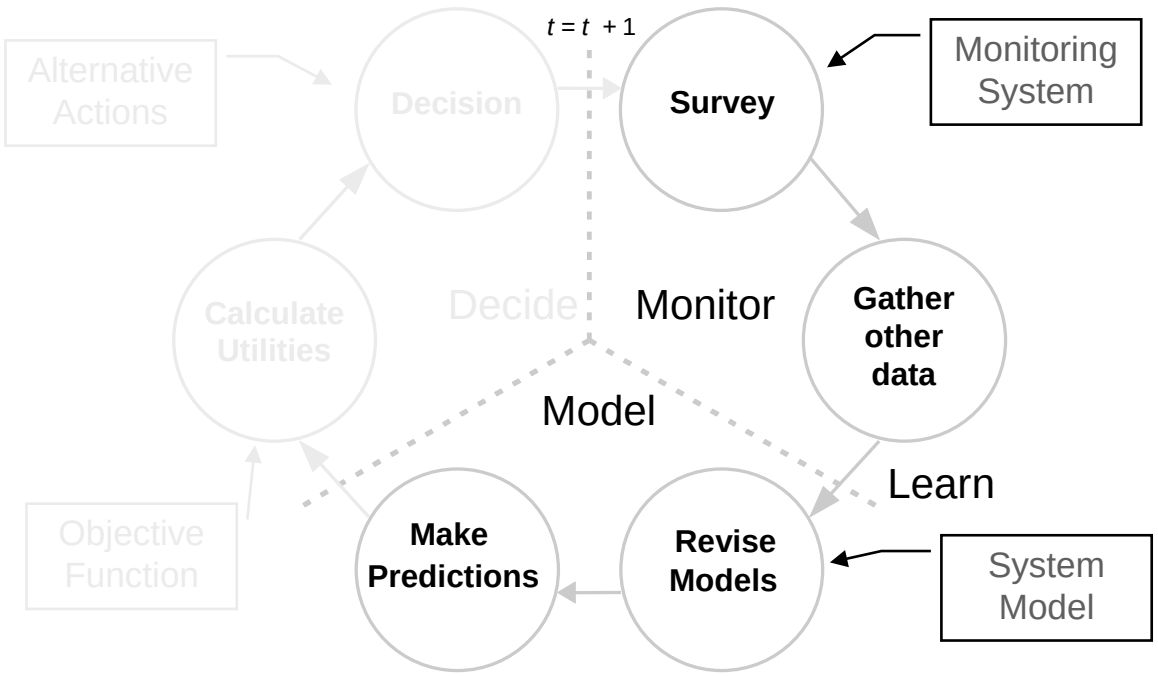
- Action drives system to new state, identified via monitoring program

- Compare estimated and predicted system state to update measures of model credibility

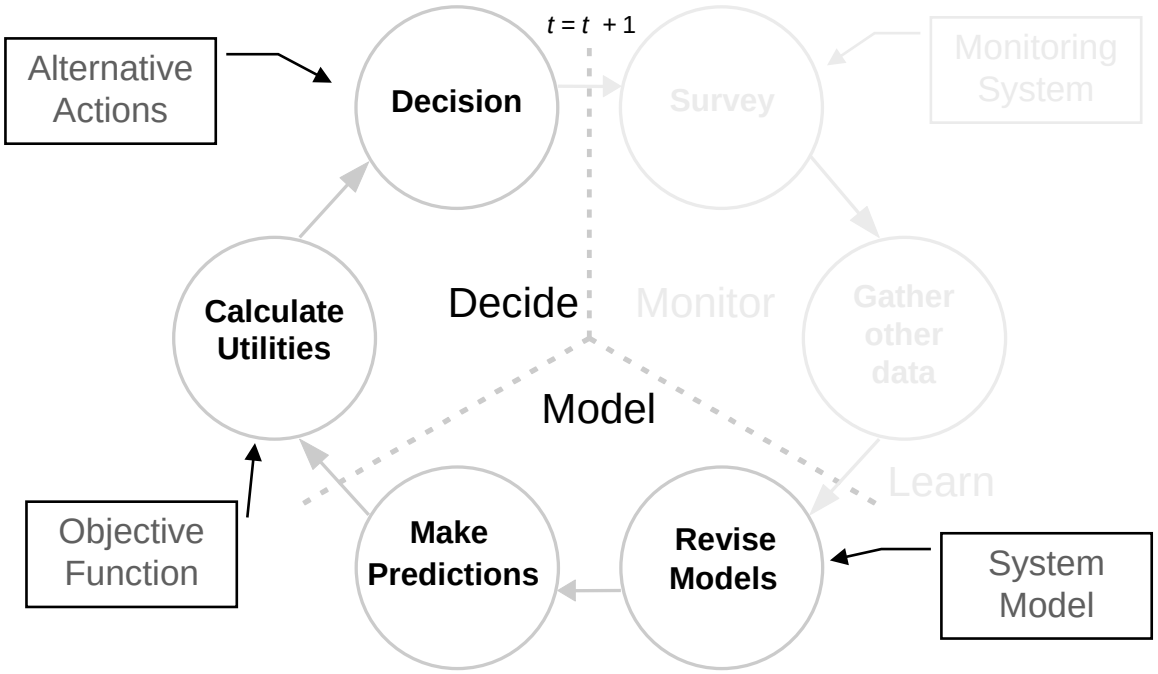
- Return to first step



Learning ("Adaptive")



Optimization ("Management")



Public Participation

Public Decisions

- Many natural resource management decisions involve public agencies

- So, many ARM applications need to involve the public in
  - Problem framing
  - Objectives setting
  - Joint fact finding
  - Implementation

- This calls for participatory, deliberative processes in which communication is paramount

Problem Framing

Framing the Problem

- That is, recognizing the core elements of the decision and how they fit together
- This is one of the hardest parts

How to frame Adaptive Management problems?

- Ask what the decision is

- Identify the elements of the decision
  - Objectives, actions, models, etc.

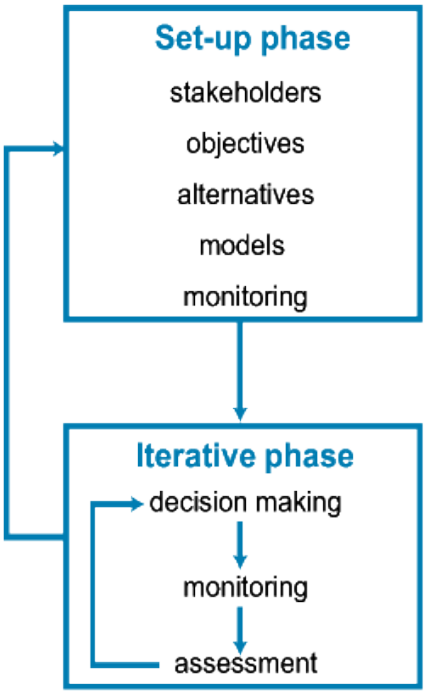
- Ask what impedes the decision
  - What uncertainty makes the decision difficult?
  - This is the motivation for Adaptive Management

Iterative Problem Framing

- Often, problem framing is iterative
  - Start with a prototype structure
  - Perform some initial analysis
  - Revise the prototype
  - Implement & gain experience
  - Revise the structure…

- It is sometimes difficult to understand the core issues of a problem until you've implemented a prototype structured approach

Double-loop Learning



Summary

- Adaptive management involves recurrent decisions in which predicted outcomes are uncertain
- Of the 4 flavors of uncertainty, the focus in AM is on structural uncertainty
- Learning in AM might be passive or active
- In practice, AM faces many obstacles (as does any informed approach to decision-making); requires persistence and openness to double-loop learning