Module J — Making Decisions under Uncertainty: Monitoring & Adaptive Management

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There is a special class of linked decision problems in which one or more of the links involve gathering additional information. A traditional research approach can be thought of as a simple linked decision where the research is the first step, and conditional on the outcome of the research, some management decision is implemented. A more complicated, but very common, situation has similar decisions made on a recurrent basis; periodic monitoring provides the opportunity to reduce uncertainty and improve management over time. In this module, we discuss research, monitoring, and adaptive management from the perspective of structured decision making.

Outline

- What do we do in the face of uncertainty?
  - Make decisions anyway
  - Conduct research to reduce uncertainty (then make a decision later)
    - Value of Information
  - Both, simultaneously
    - Adaptive management
    - The roles of monitoring

Reducing Uncertainty through Monitoring: The Value of Information

Monitoring

- We haven't talked yet about monitoring
- As scientists, we have a strong tendency to ask for more information
  - To postpone a decision until we have more information
- Why?
  - What do we think we're going to do with that information?

Information

- We often seek information to reduce uncertainty
- But we can ask, will that information change our decision and enhance our performance
  - Or is the information not relevant to the decision?

Value of Information

- Expected value of perfect information (EVPI)
  - Analytical technique
  - Allows you to assess how much your management might improve if you can resolve structural uncertainty
  - Can help you decide if it's worth the cost of gathering information

Expected Value of Information

You are losing revenue to gypsy moth infestation in your managed forest. You have 3 alternatives (possible actions): do nothing, reduce colonization, or eradicate large patches of infestation. You are trying to <u>minimize lost revenue</u>. You have two different models of how the gypsy moths (and hence your timber sales) will respond to the actions. Based on previous research, you think the likelihood of model 1 is 0.3. The predicted lost revenue is shown in the table below. How much would you pay to find out which model is true?

Lost Revenue		**Alternatives**		
weight	**Models**	Do Nothing	Reduce Colonization	Eradicate Large Patches
0.3	Model 1	$ 299K	$ 202K	$ 140K
0.7	Model 2	$ 493K	$ 256K	$ 273K

First calculate the expected value of each action <u>in the absence of new information</u>:

V("Do Nothing") = (0.3)($299K) + (0.7)($493K) = $434.8
V("Reduce Colonization") = (0.3)($202K) + (0.7)($256K) = $239.8
V("Eradicate Large Patches") = (0.3)($140K) + (0.7)($273K) = $233.1

So, in the absence of new information, you should choose to eradicate large patches, and your expected lost revenue is $233.1K.

But suppose you could fully resolve the uncertainty. If it turned out that Model 1 was correct, you would choose to eradicate large patches, and lost revenue would equal $140 K. If it turned out that Model 2 was correct, you would choose to reduce colonization, and lost revenue would equal $256K. You believe the probability that Model 1 is correct is 0.3, so the expected value, with perfect information, is:

V = (0.3)($140K) + (0.7)($256K) = $221.2

So, by acquiring the information, you've reduced the expected value of lost revenue from $233.1K to $221.2K. We say that the expected value of perfect information (EVPI) is the difference, $11.9K. So, how much would you be willing to pay for the study to resolve the uncertainty?

Class Exercise

Consider this example from Walters (1986). You have a decision whether or not to build artificial spawning channels for sockeye salmon. Your objective is to maximize the net expected value of the sockeye fishery. There is uncertainty, however, about the efficacy of these options. Under one hypothesis, the channels are not effective and there will be no beneficial response. Under an alternative hypothesis, spawning and hence, harvest potential will be greatly increased. Experts are split on these two hypotheses, so you assign equal weight to them both. It would cost $105 M to build the channels. The expected value of the sockeye fishery is shown in the consequence table below. How much would it be worth to resolve the uncertainty prior to making a decision?

		Options (net benefit)	
weight	**Models**	Do not Build	Build Channels
0.5	No response	$240 M	$135 M
0.5	Good response	$240 M	$564 M

Work space:

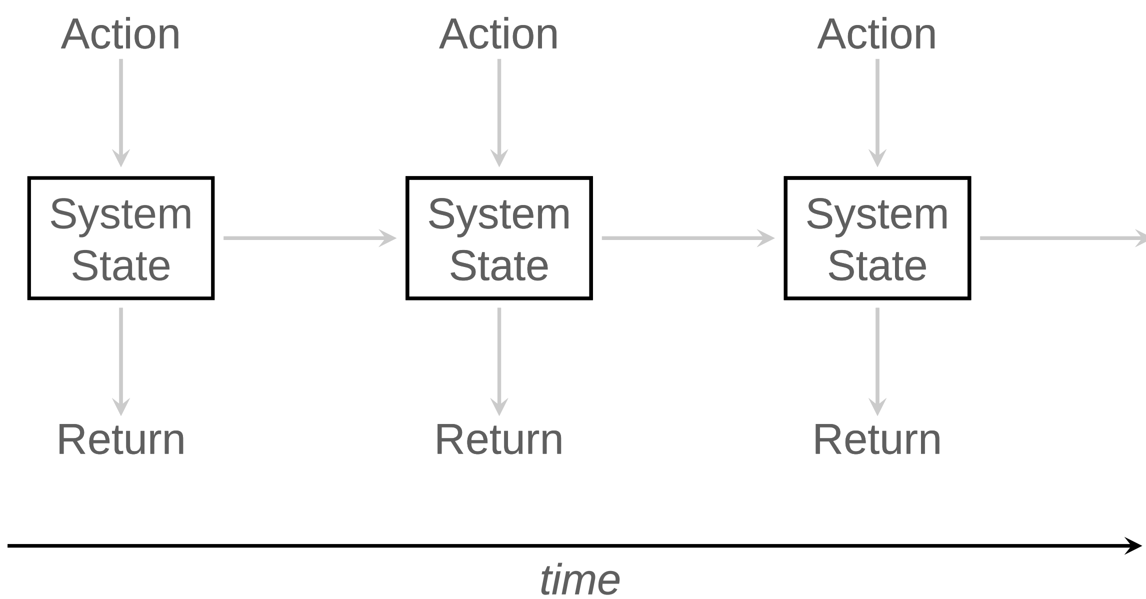
Reducing Uncertainty while Making Decisions: Adaptive Management

In an earlier module, we talked about linked decisions, decisions tied together such that the outcomes of the antecedent decisions affect the choices available and the likelihood of outcomes of the subsequent decisions. With linked decisions, it is important to analyze the whole set of decisions together; if you analyze just one of the decisions in isolation, you can make the wrong decision.

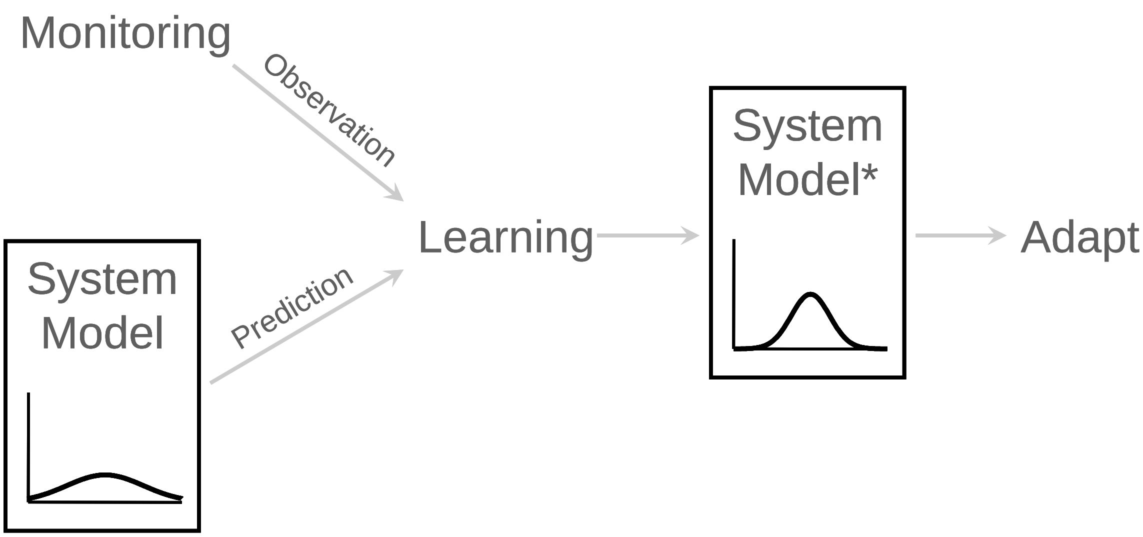
There is a special class of linked decisions known as recurrent (or iterated) decisions. These decisions are repeated over time, at regular or irregular intervals. Many of our natural resource decisions fall in this category, often because there is an annual cycle to the decision.

We approach recurrent decision in much the same way that we approach all decisions (using structured decision making, of course!). But there are nuanced differences. What makes recurrent decisions different? Two things: they are *dynamic*, and they can be *adaptive*.

Dynamic



Adaptive



Discussion

- How do the elements of SDM need to be thought of for recurrent decisions? Do they need to be formulated differently? Think about the dynamic and adaptive aspects of recurrent decisions.
  - Consider: Objectives, Actions, Models, Optimization, and Monitoring

Monitoring in the context of management

Monitoring

- Purposes
    - To assess the state of the system
    - To determine if the objectives are being met
    - To resolve uncertainty
- The development of the monitoring system should be tailored to these needs & driven by the decision context

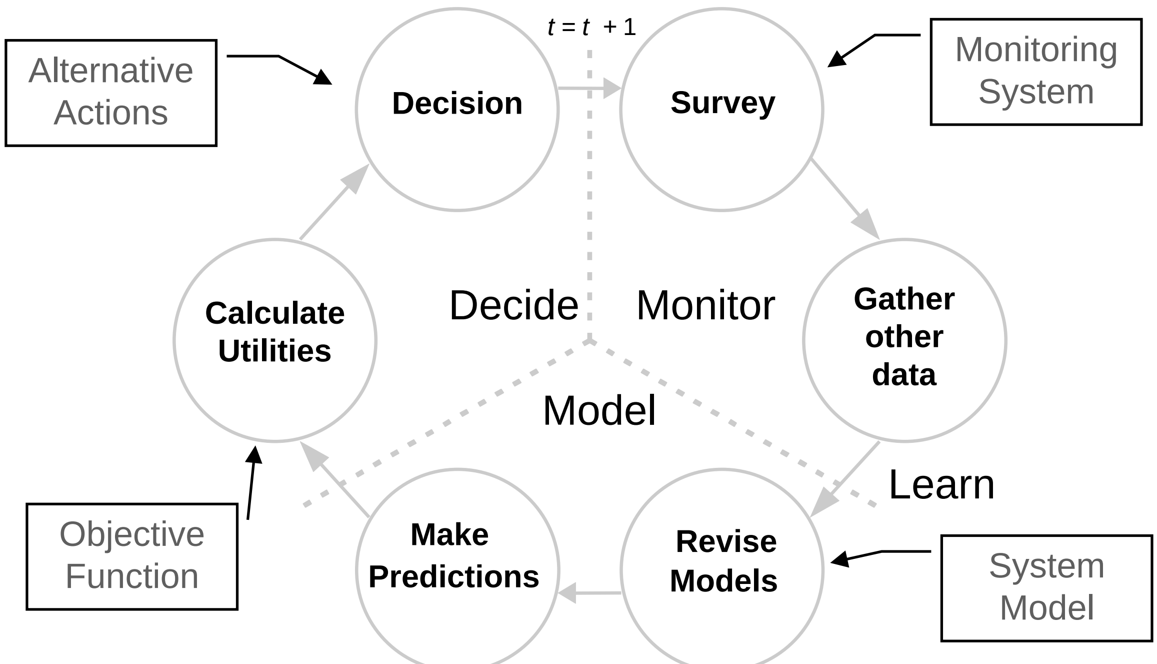
Monitoring

- Evaluation
    - Maintain open canopy (<60% closure) pine stand, with understory vegetation cover of 15-25% pinegrass, ≥5% elk sedge, <1% exotics.
- Management Trigger
    - A management prescription calls for thinning a Ponderosa Pine stand when the basal area is greater than 85 ft^2/acre.
- Learning
    - What are the differential effects of mechanical thinning vs. prescribed understory fire on vegetation composition?

Putting it all Together

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.



Problem Framing

Framing the Problem

- That is, recognizing the core elements of the decision and how they fit together
- This is the hardest part, by far

How to frame ARM 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 ARM

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