Structured Decision Making

ALC3176: Adaptive Management:
Structured Decision Making for Recurrent Decisions
Chapter 1

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Understory Management

Prescribed burn in ponderosa pine. Coconino NF, AZ.
(Allen Farnsworth, USDA FS)

Objectives

- Fundamental
  - Maintain healthy populations of native vertebrates and invertebrates in understory of Ponderosa Pine forest
- Means
  - Maintain open canopy pine stand with appropriate understory vegetation

Actions

- Alternative actions
  - Prescribed understory fire
  - Mechanical thinning of understory
- Timing
  - How frequently?
  - Under what conditions?

Models

- Predict
  - How basal area and vegetation composition change as a function of time, treatment
  - How native animal communities change as a function of habitat conditions
- These models might be mental, conceptual, or quantitative
  - But should explicitly link actions to objectives

Optimal Solution

- Found by integrating
  - Objectives
  - Actions
  - Models
- Identify the action and its timing that best achieve the objectives
- An optimal solution might call for, say, thinning whenever the basal area exceeds 85 ft^2/ac

Monitoring

(1) Evaluation

Maintain open canopy (<60% closure) pine stand, with understory vegetation cover of 15-25% pinegrass, ≥5% elk sedge, <1% exotics.

(2) Management Trigger

A management prescription calls for thinning a Ponderosa Pine stand when the basal area is greater than 85 ft^2/acre.

(3) Learning

What are the differential effects of mechanical thinning vs. prescribed understory fire on vegetation composition?

What is Structured Decision Making?

"A formal application of common sense for situations too complex for the informal use of common sense."

R. Keeney

What makes decisions hard?

- Sometimes you don't know all the possible actions
- The objectives may be complex or contradictory, or in dispute
- The system dynamics may be poorly known
- Even knowing all the other components, the solution (optimization) may be difficult to figure out

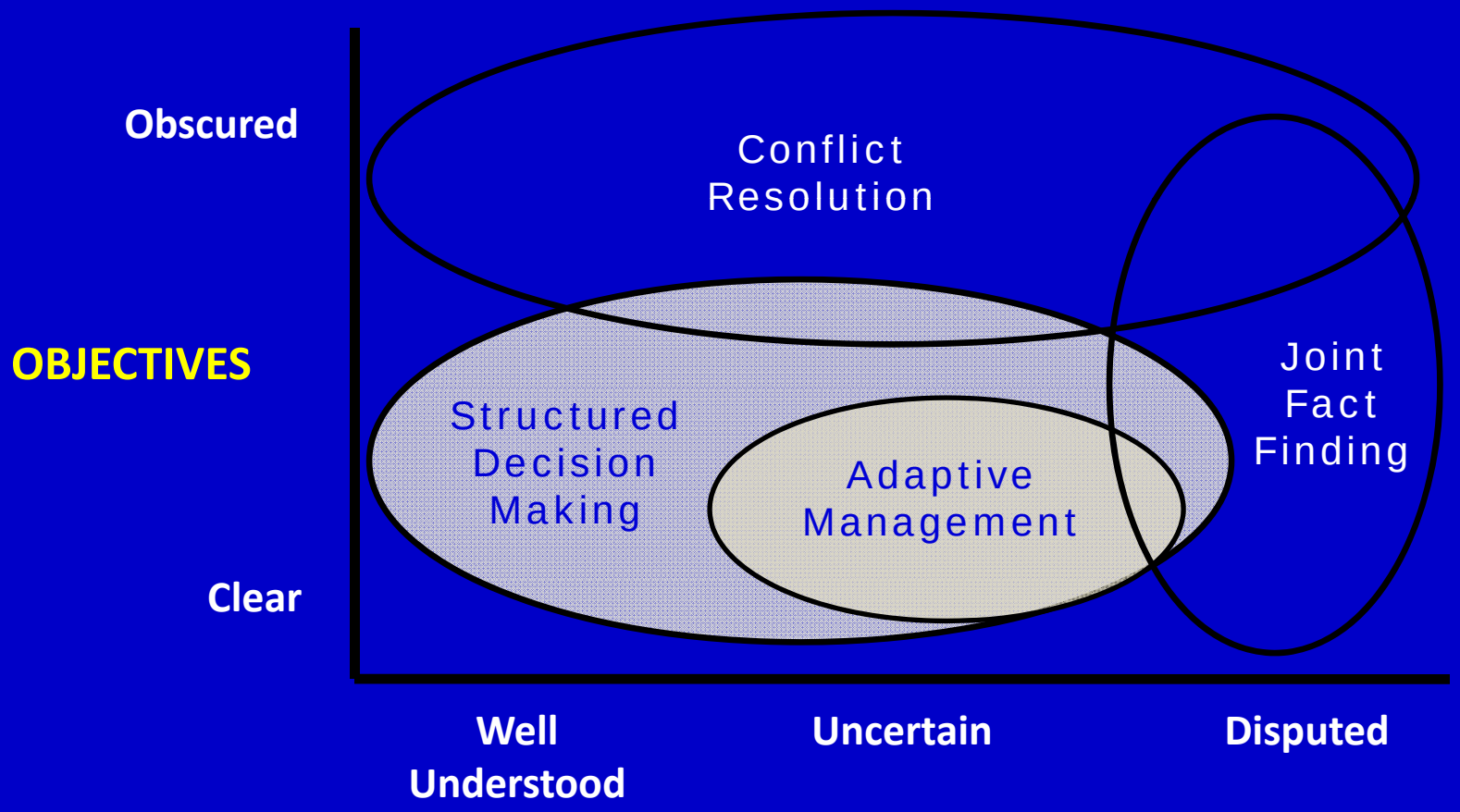
Two Key Elements

- Problem decomposition
  - Break the problem into components, separating policy from science
  - Complete relevant analyses
  - Recompose the parts to make a decision

Two Key Elements

- Values-focused
  - The objectives (values) are discussed first, and drive the rest of the analysis
  - This is in contrast to our intuitive decision-making, which usually jumps straight to the alternatives

When is SDM appropriate?



What decisions is SDM good for?

- SDM is a scalable process
  - Can be customized to the decision at hand
  - From 1-person problems to problems of national scope

Outline

- Defining the Problem
- Objectives
- Actions
- Consequences (models)
- Trade-offs and optimization
- Additional steps
- Summary

Thought Exercise

- “Thresholds”
- What might this term mean, in the context of SDM?
- Discuss with your neighbor and jot down a couple of ideas

Defining the Problem

Framing the Problem

- Who is the decision maker?
- What are the legal and regulatory contexts?

Framing the Problem

- Identify the decision's essential elements
  - Scope and scale
  - Timing and frequency

- Understand what other decisions are linked to this one

Classes of Problems

	No Uncertainty	With Uncertainty
Single Objective	Management Science; optimization tools	Classic Decision Analysis; decision trees
Multiple Objectives	Multi-attribute tradeoff tools & complex optimization	Multiple objective tools with variable inputs

Objectives

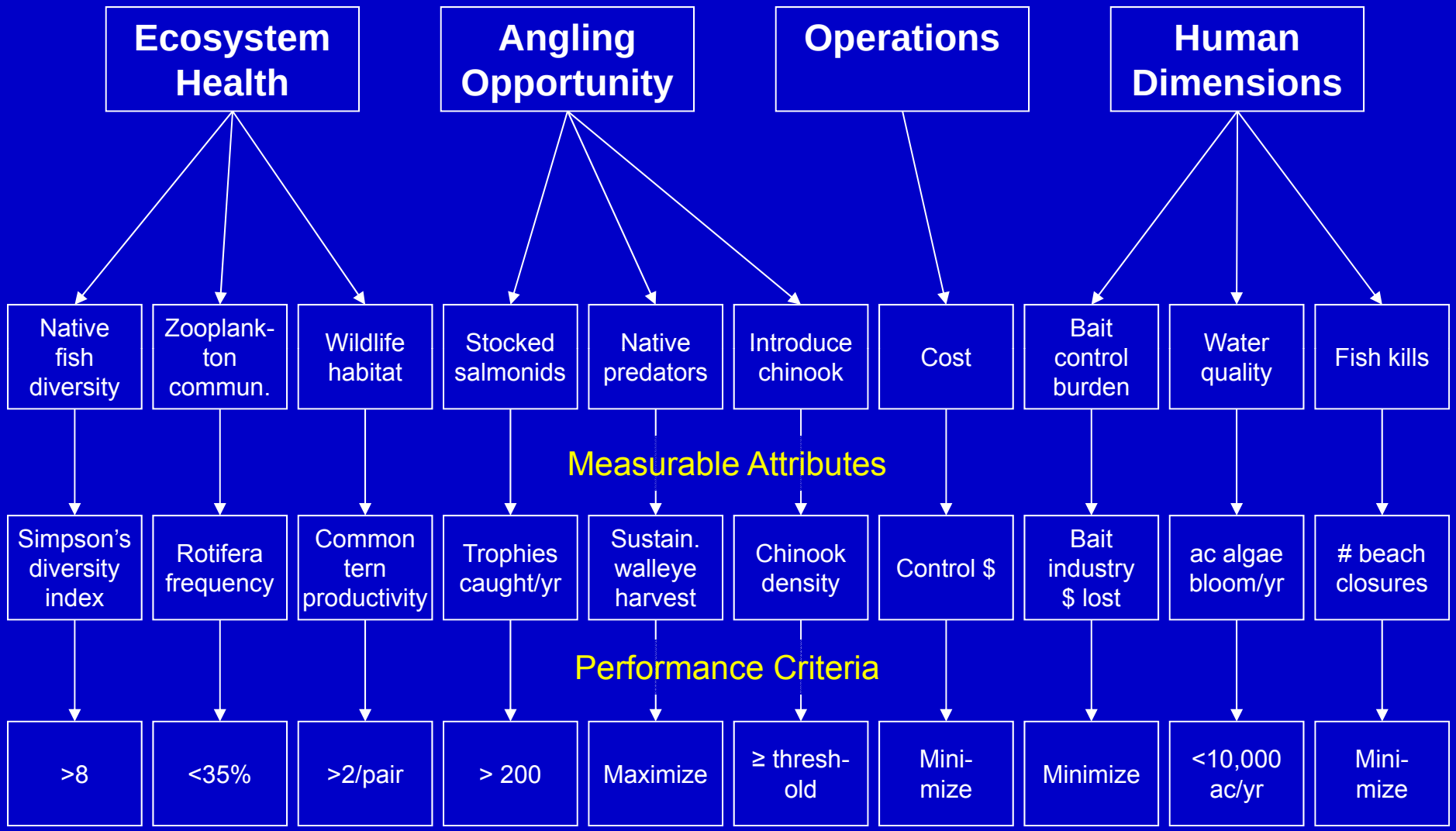
Objectives

- Explicit statement
- Should capture implied trade-offs
- The objective drives everything else
- Focus on setting objectives first

Fundamental vs. Means

- Fundamental objectives
  - Pursued for their own sake
- Means objectives
  - Pursued only insofar as they help achieve fundamental objectives

Invasive Alewives in Lake Champlain
Objectives Hierarchy



Constructed Preferences

- In many important and complex decisions, preferences may not be fully formed
- Elicitation and decision analysis processes may be the means by which decision-makers' preferences become fully formed
- The constructed preferences can be influenced by the methods of development

Alternative Actions

Potential actions

- Sometimes the list of potential actions is clear
  - But often, this is a fundamental challenge
  - Often the range of options initially discussed is unnecessarily narrow
- Ask, how can the objectives be achieved?
  - Use the fundamental objectives
  - Challenge apparent constraints
  - Don’t anchor on the initial set of options
  - Brainstorm before evaluating

Consequences (Models)

Predicting the Future

- "…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.

The Role of Modeling

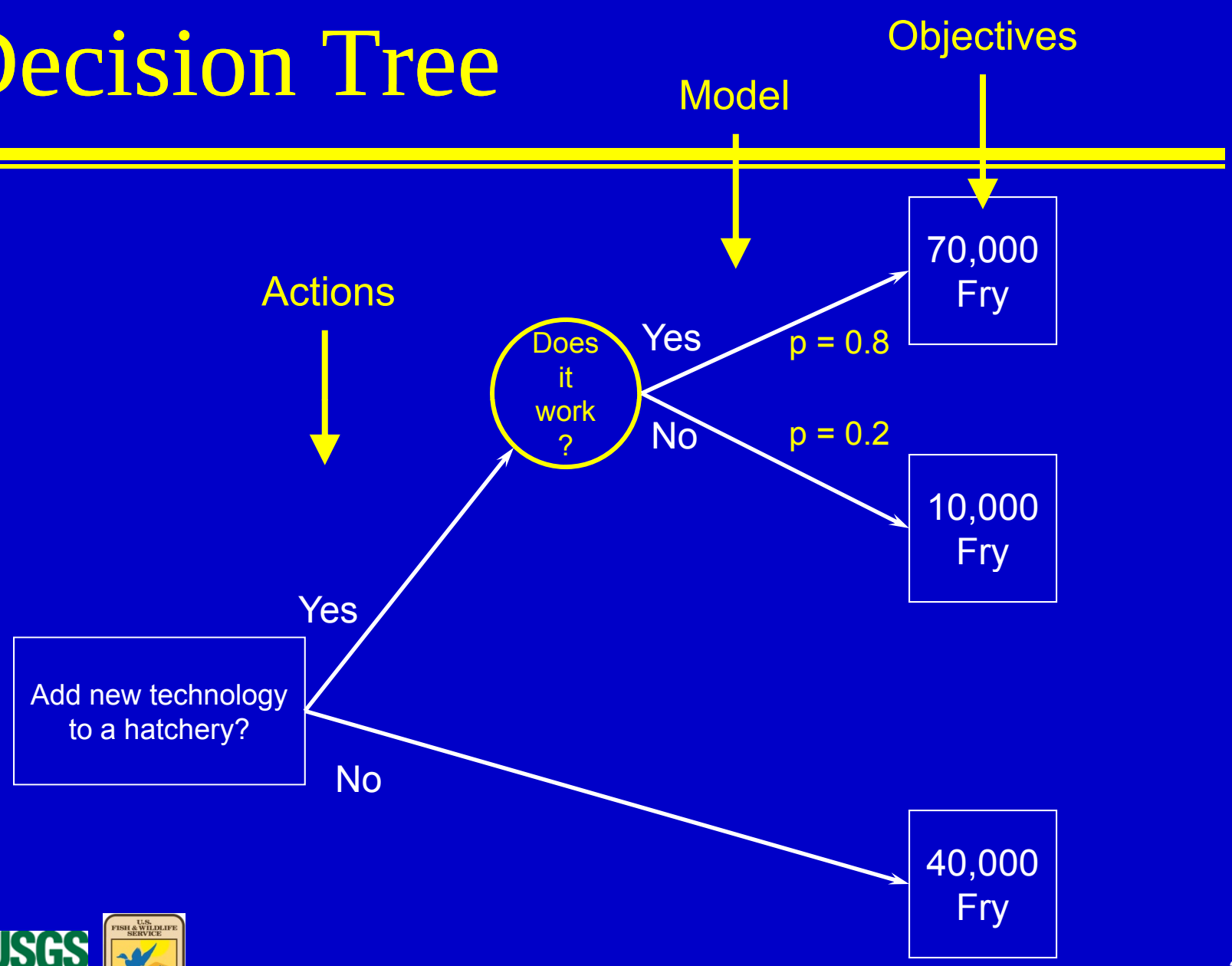
- Models link actions to outcomes that are relevant to the objectives
  - Models make predictions

- The decision context provides guidance about how to construct the model
- There is a wide range of types of models

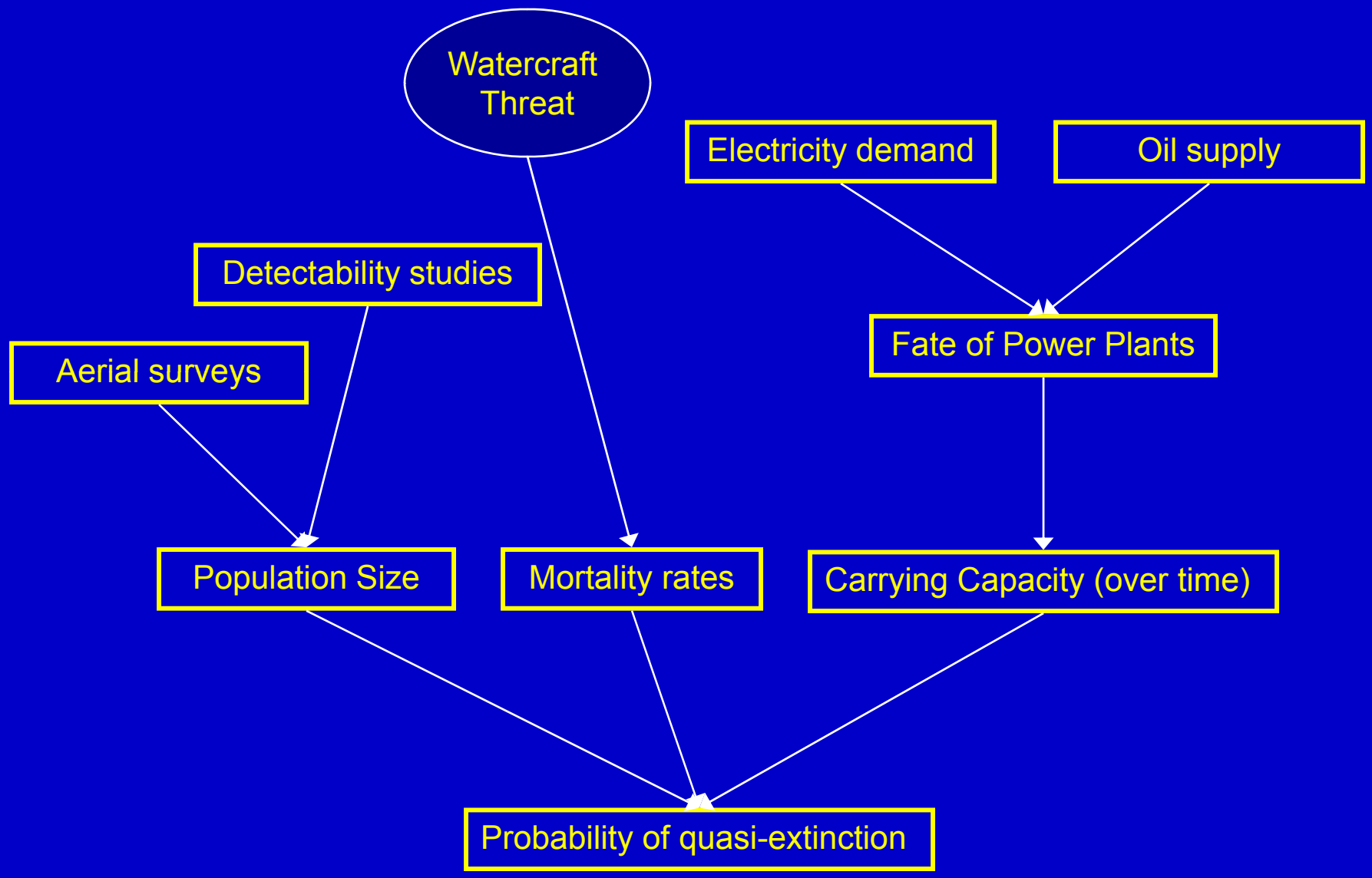
Consequence Table

Expected Return	Actions			
Objectives	Status quo	Minor repair	Major repair	Re-build
Cost ($M)	0	5	12	20
Environmental Benefit (0-10)	1	3	10	10
Disturbance (0-10)	0	1	7	10
Silt runoff (k ft^3)	3	1	5	5
Water Retention (MG)	41	42	40	41

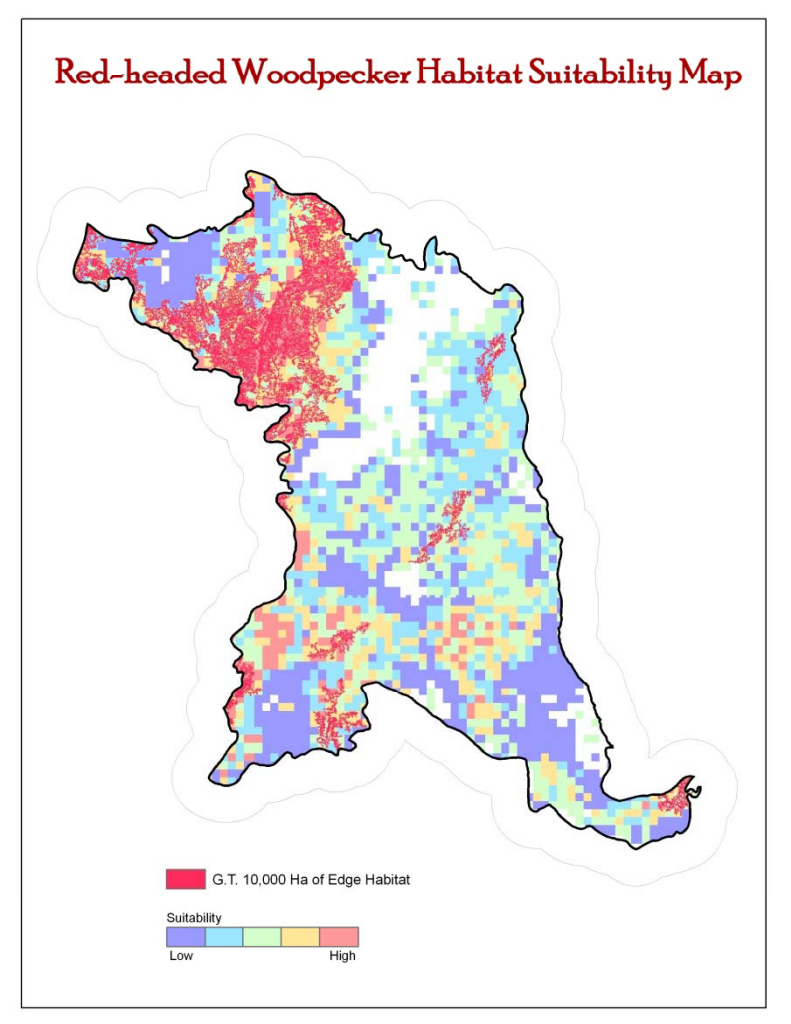
Decision Tree



Influence Diagrams & Bayes Nets



Habitat Models

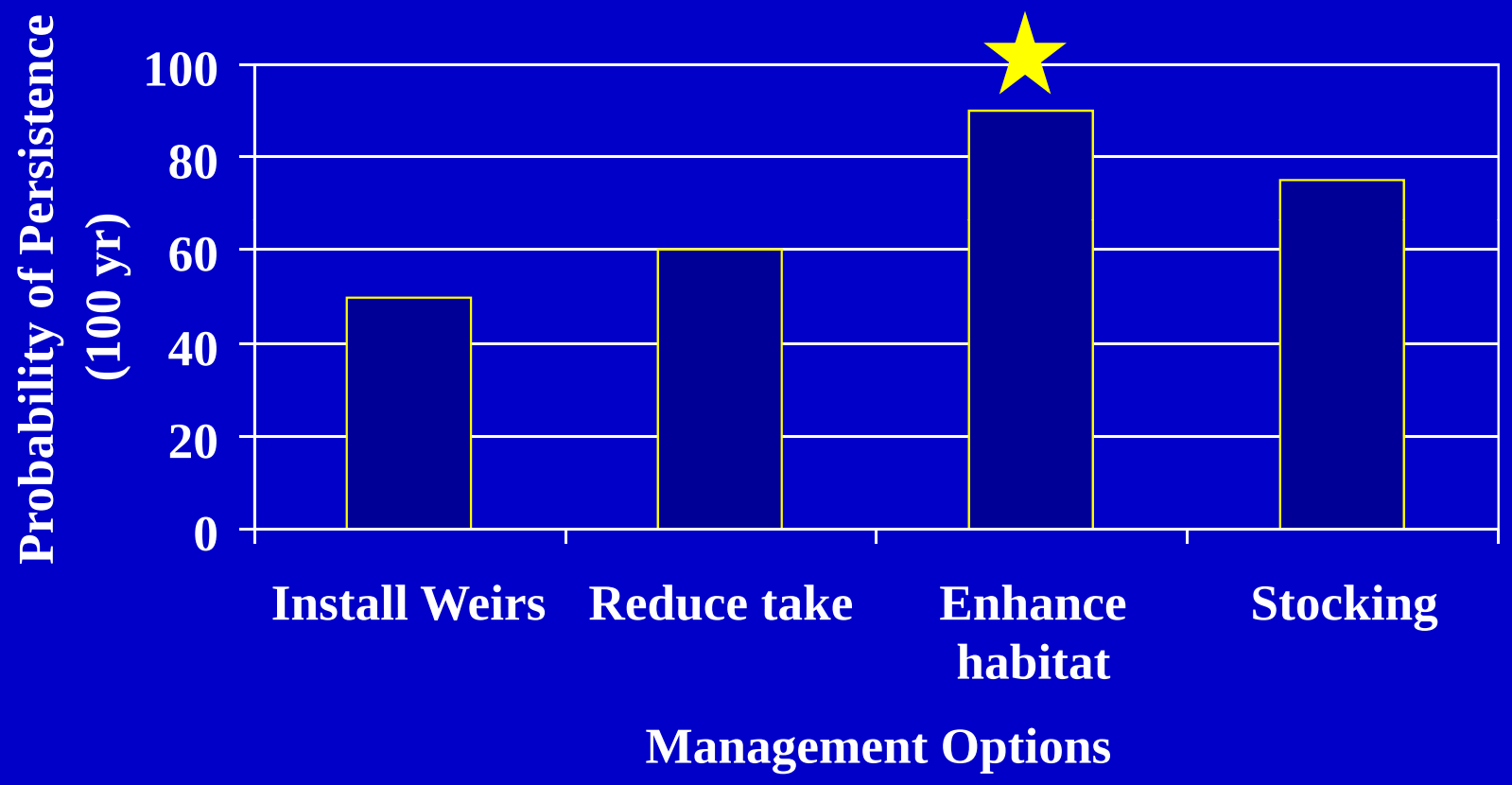


Source: Mary Mitchell, FWS/R3

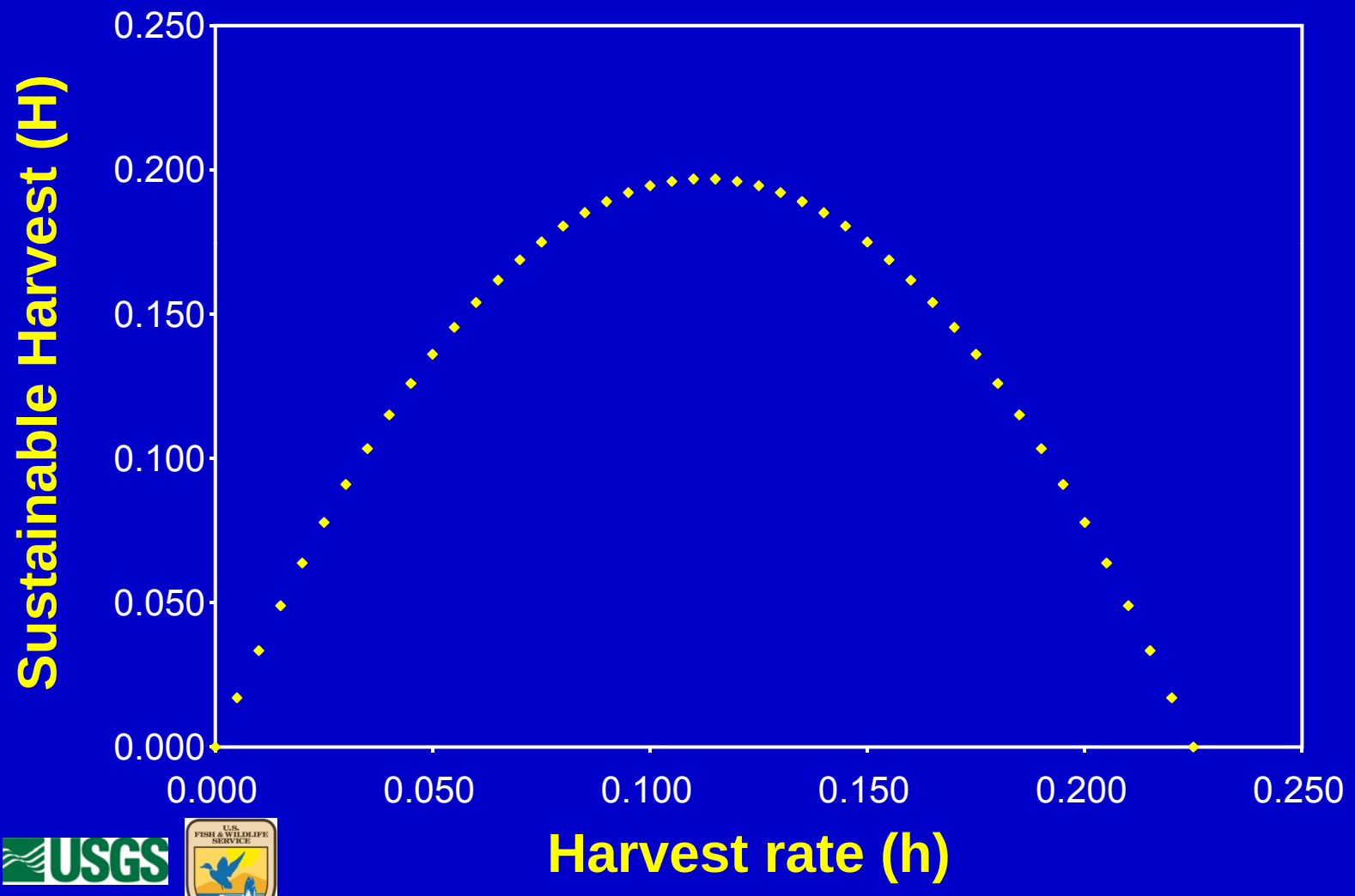
Trade-offs and Optimization

How do we “solve” a structured decision problem?

Optimization by Inspection



Single-objective Problems



Multiple-objective Problems

Expected Return	Actions			
Objectives	Status quo	Minor repair	Major repair	Re-build
Cost ($M)	0 + 1 = 1	5	12 + 2 = 14	20
Environmental Benefit (0-10)	1	3	10	10
Disturbance (0-10)	0	1	7	10
Silt runoff (k ft^3)	3 – 2 = 1	1	5 – 4 = 1	5
Water Retention (MG)	41	42	40	41

Dominated Alternative

Irrelevant Objective

Even Swap

Types of Thresholds

- Objective thresholds
  - Performance criteria; part of the objectives
- Ecological thresholds
  - Switch points in the system; part of the model
- Decision thresholds
  - Trigger points for action; arise out of the optimization

See: Martin et al. 2009. Ecological Applications 19:1079-1090.

Additional Steps

1. Recognize Uncertainty

- Smart choices don't always result in good outcomes
  - Because of uncertainty
- Need to explicitly build uncertainty into decision analysis
  - Quantitative expression of uncertainty
  - Risk attitudes: making decisions in the face of uncertainty about outcomes

2. Sensitivity Analysis

- Examine the how the optimal decision and the expected performance is affected by
  - Assumptions
  - Parameters in the models
  - Levels of uncertainty
  - Weights on objectives
  - The problem framing itself
- Ask whether the decision is robust to uncertainty
  - If not, consider revising aspects of the problem

3. Review and Revise

- Decision analysis can be iterative
  - Develop a prototype
  - Perform sensitivity analysis
  - Revise as appropriate
- Work from broad levels to details
  - Get the framework right, first

Summary

PrOACT+

- A guide for defensible decision-making
  - Problem decomposition
  - Values-focused thinking
- Steps
  - Problem
  - Objectives
  - Actions
  - Consequences
  - Trade-offs
  - Additional steps

Roles

- Policy
  - Decision maker
  - Stakeholders
  - Subject matter experts (e.g., legal)
- Science
  - Subject matter expert (biological)
  - Modeling expert
- Integration
  - Decision maker
  - Decision analyst
  - Facilitator

“Soft” Approaches

- May be more qualitative in nature
- But nevertheless use the same approach for analysis:
  - Enumerate actions
  - Articulate objectives
  - Predict consequences of actions in terms of objectives
  - Examine trade-offs
  - Perform sensitivity analysis to understand effects of uncertainty

Goal & Benefits of SDM

- Improve the quality of decisions
- Decision processes that are
  - Transparent
  - Explicit
  - Deliberative
  - Able to be documented
  - Replicable