**OBJECTIVES**

By the end of this module, you should be able to:

* Understand the need for prediction to evaluate alternatives relative to objectives
* Construct a consequence table and use it to qualitatively compare alternatives
* Build an influence diagram
* Explain the role of modeling and desired properties of models in decision analysis
* Understand the roles of both empirical estimation and expert judgment in prediction of consequences

**PREDICTION**

***Predicting consequences***

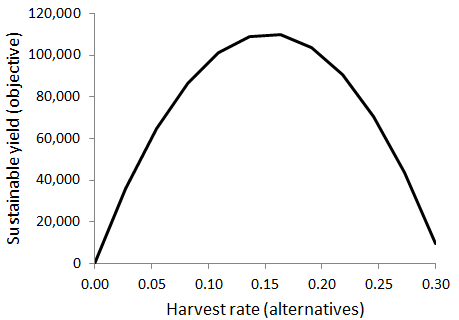
* How should we select the best alternative?
* We want the best outcomes from our decision
* We need to predict what we think would happen in the future if we implemented each of our alternatives
* What are the outcomes of interest?
* Fundamental objectives (and associated measurable attributes) define what we care about in a decision

***Single‐objective examples***

* Commuting to work
* Objective: arrive on time for a meeting at 8:30 am
* Alternatives: leave home at 7:30, 7:45, or 8:00 am
* Consequences: how long will it take to get to the office?
* Regulated harvest from a population
* Objective: maximize sustainable yield
* Alternatives: annual harvest rates [0–0.3]
* Consequences: predict sustainable yield at different harvest rates
* Set back succession on a 160‐acre grassland unit
* Objective: minimize financial cost
* Alternatives: burn, mow, graze
* Consequences: How much would it cost to burn, mow, or graze the unit?

***Summarizing predicted consequences***

* If your alternatives are on a continuous scale, use a graph
* Predicted consequences are represented by a line



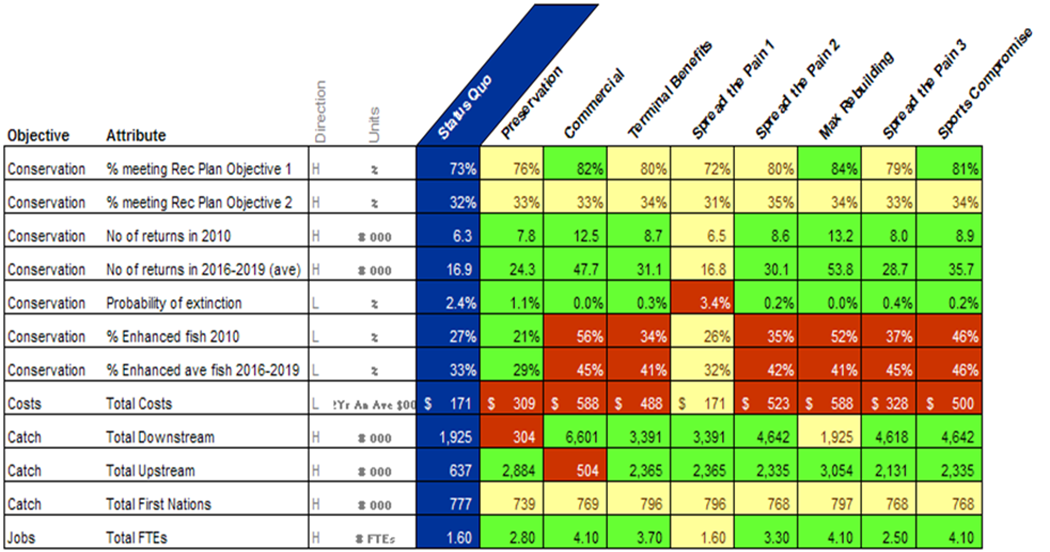
* If your alternatives are discrete, use a table

|  |  |
| --- | --- |
| **Alternatives** | **Cost to treat 160 acres**  **($, objective)** |
| Burn | 800 |
| Mow | 480 |
| Graze | 1000 |

* If there are ≥2 objectives, add an additional column for each objective

|  |  |  |  |
| --- | --- | --- | --- |
| **Alternatives** | **Financial cost** | **Native plant diversity** | **Invasive species control** |
| Burn | 800 |  |  |
| Mow | 480 |  |  |
| Graze | 1000 |  |  |

* Consequence table
* Construct a table with:
* Alternatives in the first column
* Each objective (and measurable attribute) in a separate column
* You can switch this up if it makes it easier for the decision maker to make comparisons
* Benefits
* Summarizes essential elements of the decision problem
* i.e., objectives, alternatives, and consequences
* Facilitates comparison of the alternatives
* Exposes relevance of uncertainty
* Exposes key tradeoffs
* Cultus Lake sockeye salmon conservation example (Gregory and Long 2009)
* Conditional formatting with color can help summarize information in a large table



How do you make the predictions (e.g., put numbers in the cells of a consequence table)?

**MODELING IN DECISION ANALYSIS**

Models

* All predictions are based on a model, explicit or not
* A model is any simplified representation of reality intended to be useful for a particular purpose
* “All models are wrong, some are useful” – George Box

***Role of modeling in decision analysis***

* Prediction
* The main need: output of the consequences step of PrOACT
* Want predictions to be “good”
* Better predictions lead to better decisions
* Structuring the analytical problem
* Developing a model helps us with working through the complexity of the system helps us improve and refine our understanding of how the world works
* Decomposing the full system into subcomponents and the relationships among them fosters assessment of what is essential to the decision context and what might not be
* Capturing large amounts of complex information in a way that is accessible
* Transparency
* Every prediction, even a guess, is based upon a model of how we think the world works
* Goal is to describe the model, no matter how simple or sophisticated it is
* Encourages a common understanding among people working on the decision problem
* Fosters communication with stakeholders who are not directly involved in making the decision

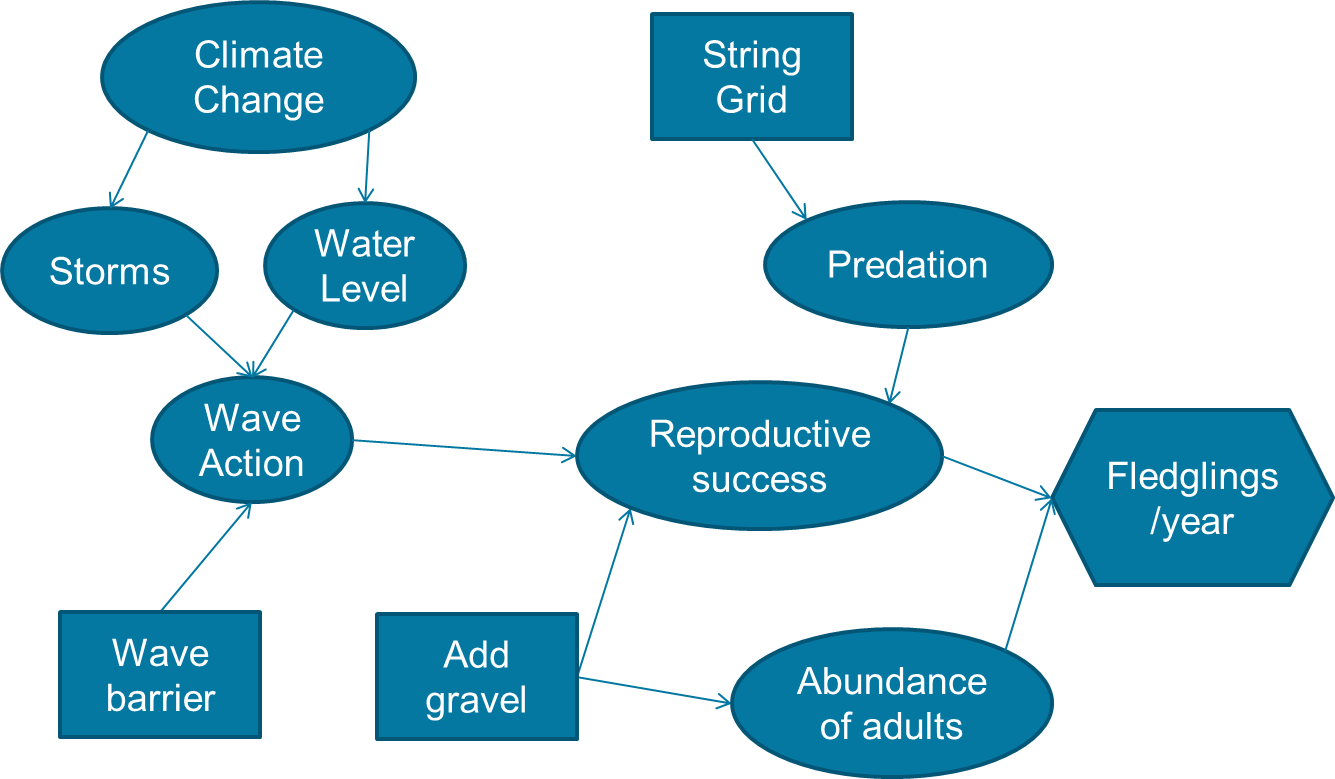
***Desired properties of a model in a decision context***

* Model design is driven by the decision context
* Context = the purpose of the model
* The decision may not require a full model of the socioecological system in which the decision is embedded
* Parsimonious
* Includes all essential components of the system that could affect predicting the relevant consequences of possible alternative actions
* Does not include any components that are not necessary for making good predictions, to minimize distractions and unnecessary work
* How do you know if something is essential or unnecessary?
* Incorporates an appropriate articulation of uncertainty
* First prototype of a model often does not include uncertainty (i.e., it is deterministic)
* There is always uncertainty, but is it great enough to be relevant to the decision (i.e., should the model be stochastic?)
* More below in this module (Developing quantitative models) and in Modules 11 (Risk problems) and 12 (Information problems)

***Developing qualitative models***

* How to construct an influence diagram
* Fundamental objectives (measurable attributes) are the model outputs (Hexagons)
* Alternative actions are model inputs (Rectangles)
* Add nodes for system components that link the alternatives to the objectives (Ovals)
* Add arrows to indicate influences
* Add nodes and arrows for other “drivers” that will influence the future status of our objectives
* e.g., sources of mortality other than harvest by hunters
* Remember to seek parsimony – a balance between capturing all essential components of the system and excluding unnecessary components
* Start very simply
* Only add complexity if you think it will be relevant (i.e., will make a difference in predicting consequences to discern among alternatives)

Example influence diagram: Managing common terns on an island in Mille Lacs National Wildlife Refuge in Minnesota (modified from Blomquist et al. 2012, unpublished)



* Value of influence diagrams
* Prediction
* Conditioning people for making expert judgements (i.e., predictions based on informed beliefs)
* See “Expert judgment” = predictions based on informed beliefs
* Basis for developing quantitative models (see next section below)
* Problem framing
* Discussing and making determinations about…
* the relevant spatio‐temporal scale
* what is inside and outside the scope of the decision
* Generating alternatives
* Once the main components and drivers of the system are laid out you can look for new ways to influence the system
* Communication
* Seeking common understanding among stakeholders, justifying a decision to others

***Developing quantitative models***

* Developing the structure of a model
* Selecting the variables, or parameters, to include
* Start very simply, and only add complexity if you think it will be relevant
* Start with an influence diagram
* Convert nodes to parameters in a mathematical formula
* Use iterative prototyping
* Does adding a particular parameter or more complex structure affect the predictions significantly?
* Example: single objective to maximize abundance of a population
* Start with Nt+1 = Nt + Births – Deaths, or Nt+1 = Nt + (Nt × r)
* Is immigration or emigration significant?
* Is density dependence significant?
* Is it beneficial to include different sources of mortality?
* Would the comparison of alternatives be different if demographic or environmental stochasticity were added?
* Estimating parameters
* Empirical estimation
* When empirical data are available and there is time to analyze them
* Rely on robust statistical methods when possible
* Expert judgment
* When empirical data are not available or there is not time to analyze them
* A lack of data often cannot or should not delay a decision
* Elicitation (Martin et al. 2012)
* Experts have knowledge and experience that can be useful in making predictions
* Use a structured approach and established methods for elicitation
* Experts are just as susceptible to cognitive biases as other people
* Expert elicitation is a mature field with established best practices
* Example elicitation methods
* Four‐point elicitation (Speirs‐Bridge et al. 2010)
* Plausible lower bound
* Plausible upper bound
* Most likely value
* Level of confidence that the interval includes the true value
* Delphi method for elicitation from a group
* Elicit judgments individually and independently
* Everyone’s judgments are displayed together but anonymously
* Strictly for review
* Method often modified to include group discussion
* Repeat the first 2 main steps until all experts are comfortable with their judgments
* Benefits
* Prevent anchoring on initial judgments or the judgments of others
* Reduce overconfidence in the precision of judgments
* Minimize the likelihood of group think or the effect of dominance in group dynamics
* Cultus Lake sockeye example:
* many objectives, short time frame
* used existing simulation models and elicitation of expert judgments
* different models for different objectives
* Uncertainty in models
* Structural uncertainty
* Uncertainty about which model structure is best, or whether a variable has an effect
* Can use different models to represent competing hypotheses
* See Module 12 (Information problems)
* Parametric uncertainty
* Uncertainty in the value of a parameter or the effect of a variable
* Can be represented by a confidence interval or probability distribution
* Both types reduce the precision of predicted consequences
* How do we deal with uncertainty in decision-making?
* Make a decision while dealing with risk (Module 11, Risk problems)
* Consider learning before deciding (Module 12, Information problems)
* Learn while managing (Module 13, Dynamic decision problems)
* “…unacknowledged uncertainty leads to **optimistic expectations** that cannot be satisfied… and to actions that are blind to substantial qualitative and quantitative uncertainties that, if they were apparent, **would lead to different decisions.**” (Burgman et al.2005)

**THE INTERACTION OF SCIENCE AND POLICY**

Consequence analysis is a scientific endeavor

* Predictions of consequences should be based upon models that represent the most reliable, unbiased understanding of how the world actually works
* Consequence analysis, however, is embedded in a value‐laden decision context.
* The design of the models that scientists develop and apply should be based upon a decision‐specific purpose
* Scientists need to understand:
* the framing of the decision
* the attributes that will be used to evaluate the alternatives
* Similarly, decision‐makers and policy‐makers do not rely on science alone, but they need to understand the scientific predictions and how they relate to the other decision components

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