Module E — Consequences

Where does predicting consequences fit?

Recall PrOACT

- We now need to understand the **Consequences** of different **Actions** in terms of our **Objectives**
  - **Consequences** link **Objectives** and **Actions**
- **Models** (in SDM) are tools that help us predict **Consequences**
  - Need not be complex in all cases
    - Will I make an 8:30 meeting if I leave home at 7:45?
A Simple SDM example
Predicting Consequences

Consequence table:
- Highly useful
- Puts a lot of information in a concise and orderly format
- Easy to compare alternatives, objective by objective
- Initial framework for assessing tradeoffs

Predictions and models:
- Requires projection into the future
- Uses common scale within each objective
- Includes ‘hard data’ (e.g., total cost) and subjective assessment (e.g., friendliness)
- Makes the most of available information, including ‘expert opinion’
- Reports appropriate level of precision
- Incorporates uncertainty

Cultus Lake Sockeye
Role of Modeling in SDM

- **Models**
  - Range from simple to complex
  - May or may not be quantitative
  - Involve little or great uncertainty
- **The characteristics of the model are case-dependent**
  - That is, model structure depends upon
    - the specific role of the model
    - the other components of the decision framework
  - Inputs are based on actions
  - Outputs are measurable attributes

Through modeling we:
1. Structure the analytical problem
2. Lend transparency to the analysis
3. Develop predictions of consequences

Let’s explore these three benefits models offer:

1. **Structuring the Analysis**
   - Often determining the consequences of alternatives involves complex and multiple analytical steps
   - Models are useful for thinking through these problems
     - by graphically displaying the problem, the key elements and the relationships among them are more easily discerned
     - by decomposing the problem, the analytical steps are more readily apparent

2. **Transparency**
   - Every decision maker uses some kind of model to predict the consequences of alternative actions
   - In SDM, we want to make these models explicit and available to everyone involved
   - During model development we:
     - Illustrate key elements of the problem and relationships among them
     - Capture complex information

3. **Predicting Outcomes**
   - And finally...
   - In order to compare and contrast alternatives, we must predict the future outcomes of each
     - and specifically, in terms that are relevant to our objectives
Quick exercise:

- A USFWS Refuge manager has to decide which of 3 areas adjacent to the Refuge to acquire. Each of the areas contains current or potential habitat for an endangered butterfly.
- She would like to minimize the probability that the butterfly will go extinct, while minimizing costs.
- She wants you to build one or more models to help her make this decision

Answer the following:

- What will the model(s) need to be able to predict?
- What are benefits of building explicit predictive models in this case?

Examples of Models

Conceptual models
- Influence diagram
- Systems diagram

Predictive models
- Population model
- Habitat model
- Bayesian Belief Network
Model Choice
In building (or selecting) a model, the important questions to ask are…

- “What will help me make better predictions?”
  - Ecological understanding is not the focus unless it improves prediction

- “What are the pertinent model variables?”
  - Model inputs are essentially the alternatives
    - e.g., feral cat control affects juvenile survival
  - Model outputs are essentially the objectives
    - e.g., maximize N at year 20

- “What uncertainty needs to be included?”
  - Incorporate that uncertainty that affects the decision

How much complexity is useful?

Annual Cycle of rufa Red Knots

Delaware Bay stopover

South American wintering/stopover sites

Weather

Horseshoe Crab Eggs on Beach for Red Knots

Harvest Horseshoe Crabs?

Habitat Management
Influence Diagrams

Conceptually link the actions to objectives
Distinguish between relationships that can and cannot be controlled

- “Nodes” for
  - decisions
  - chance events
  - outcomes
  - calculations

Different Shapes for Different Elements

- Rectangles: decision node
- Oval: chance node
- Hexagon: outcome node
- Rounded rectangle: calculation or constant

![Influence Diagram Example](attachment://influence_diagram.png)
Representing relationships in influence diagrams

**Relevance**

- **R** → **B** → **F**
- Chance associated with node **R** & decision in node **B** are *relevant* to assessing chance events in node **F**.
- **R** = rain fall
- **B** = controlled burn
- **F** = wild fire

**Sequence**

- **H** → **W** → **S**
- Decision in node **S** is made *after* decision in node **H** & *after* knowing the chance event in **W**.
- **H** = completes homework
- **W** = weather
- **S** = play soccer

**Influence Diagram vs. System Model**

- In influence diagrams
  - Nodes and arrows represent belief or knowledge about how values of variables affect the values or probability distributions of other variables
- In system models
  - Nodes represent stocks, sources, and sinks of conserved quantities.
  - Arrows represent flow of materials, e.g., births, deaths, migrations, etc.
Horseshoe Crabs and Shorebirds Influence Diagram

Horseshoe Crab System Model

- Harvest Horseshoe Crabs?
- Weather
- Horseshoe Crab Eggs on Beach
- Habitat Management

Number Spawning Crabs

- Crabs Harvested (Quota)
- Surface Eggs
- Deep Eggs

- Weather
- Management Actions

- Eggs Hatch and Develop To Year 1
- Pre-recruits

Juvenile Crabs

8 year delay $\Pi_{S_0}(S)$
Establish a reserve?

- Consider an endangered species that may benefit from a new reserve
- Decision: Establish a reserve or not?
- Objective: Species persistence

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<th>Choice</th>
<th>Outcome</th>
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Summary

- Models
  - Link objectives to actions
    1. structure the analytical problem
    2. lend transparency to analysis
    3. predict the consequences of alternatives
  - May be quite complex or very simple...
    1. It depends on the decision problem and the necessary precision
- Influence diagrams
  - Useful to develop a shared understanding of system behavior
  - Concisely convey complex information