University of Missouri

Workshop – An Overview of Structured Decision Making for Natural Resources

Brielle K Thompson – Missouri Cooperative Fish & Wildlife Research Unit

Workshop: An overview of Structured Decision Making for natural resources, Missouri Natural Resources Conference 2025, Osage Beach, MO

Modified from: An overview of Structured Decision Making for natural resources, Midwest Fish and Wildlife Conference 2025, St. Louis, MO & Fundamentals of Structured Decision Making TWS Conference Workshop 2023 & an Overview of Structured Decision-Making Washington Department of Fish and Wildlife 2022-2023

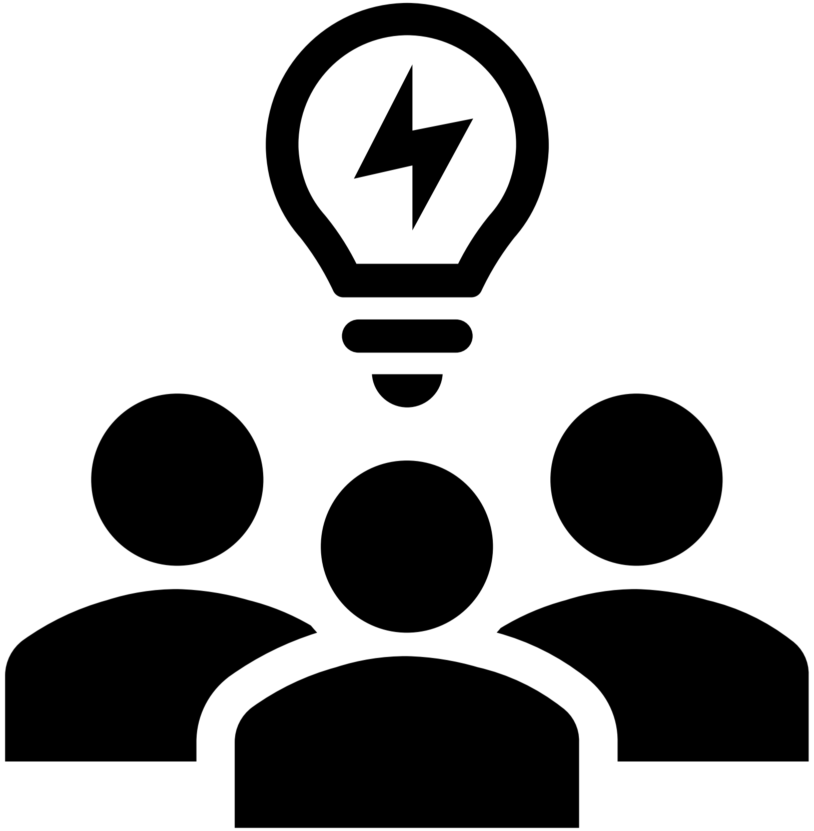
Instructor:

Brielle Thompson, PhD

- Postdoctoral Fellow at the University of Missouri (Mike Colvin, Craig Paukert)
- Received PhD in June 2024 at the University of Washington
    - Advisors: Sarah Converse & Julian Olden
    - Focused on decision making applications to aquatic invasive species
- Current project: Developing Invasive Prussian Carp monitoring protocols

Course Objectives

- Add some tools of Structured Decision Making to your toolbox
- Understand the general steps of PrOACT
- Practice 'Thinking like a Decision Analyst'



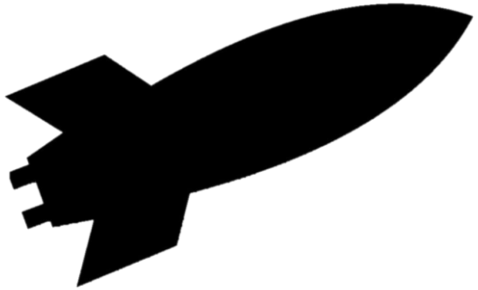
Logistics

- Website →
- Agenda: 1-3pm

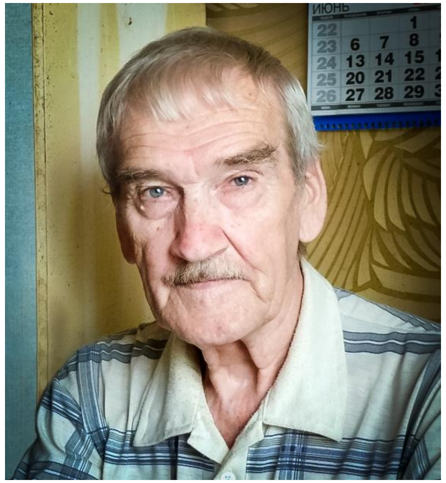
Module	**Time**
1. Motivation for SDM	1-1:20 (20 minutes)
2. Problem Framing	1:20-1:40 (40 minutes)
3. Objectives	1:40-2 (20 minutes)
------------------------Break------------------------	**2-2:05 (5 minutes)**
4. Alternatives	2:05-2:20 (15 minutes)
5. Consequences	2:20-2:35 (15 minutes)
6. Tradeoffs	2:35- 2:55 (20 minutes)
7. Conclusion	2:55-3 (5 minutes)

Motivation for Structured Decision Making

Humans are **GOOD Decision Makers**



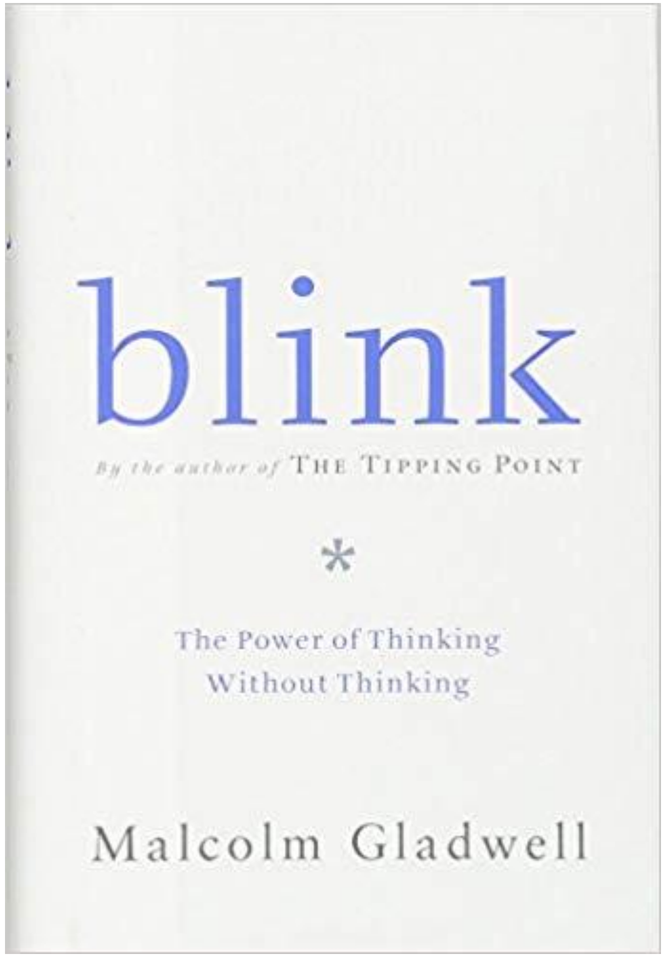
Averting nuclear war during the Cold War



Stanislav Petrov – Judged potential U.S. missiles as an alert system malfunction (it was!)

JFK – Placed a naval blockade around Cuba instead of going into war

Blink



- Gladwell argues that our intuitive decision-making skills are excellent in certain circumstances

- Isn't the ability to make good decisions the hallmark of our species?

Humans are **BAD Decision Makers**

Quick Puzzle to Test Your Problem Solving

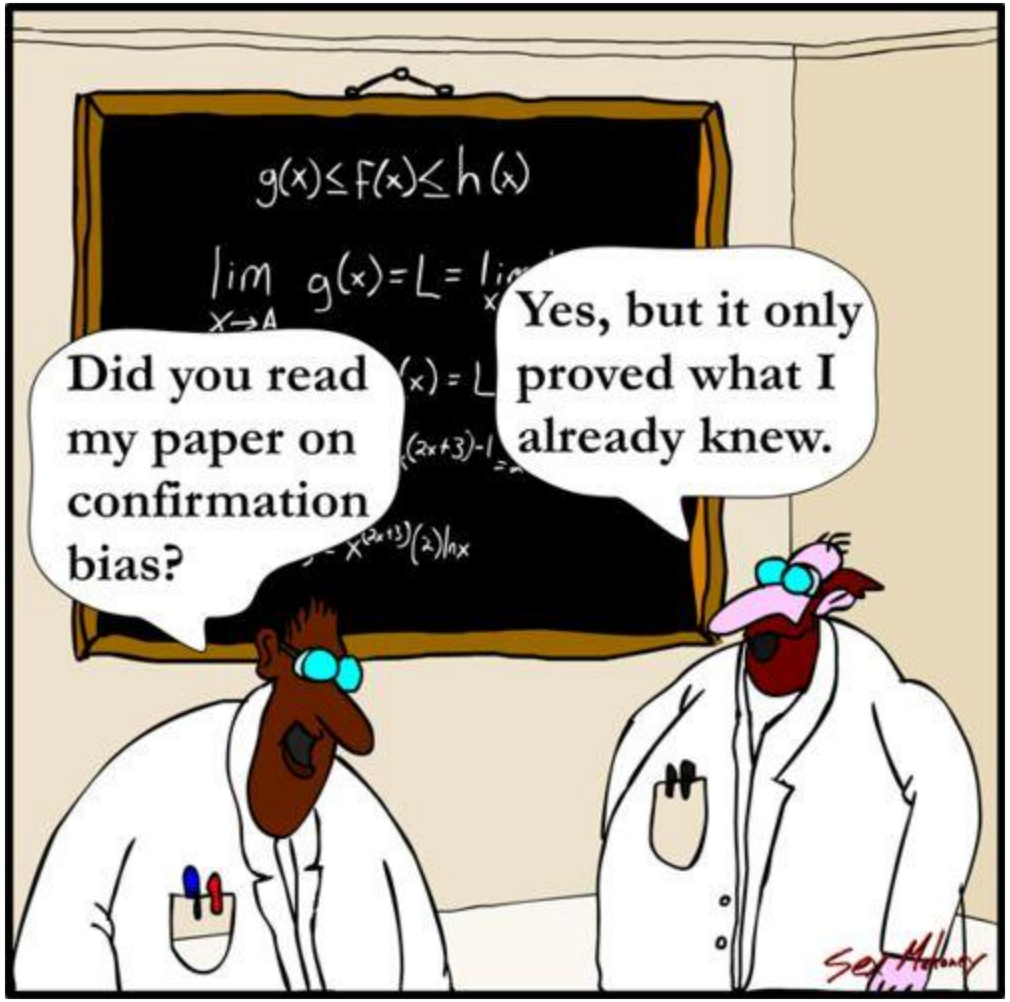
(Source: *The New York Times*)

- I’ve chosen a rule that some sequences of three numbers obey — and some do not. Your job is to guess what the rule is.
    - The sequence: 1, 2, 4 obeys the rule.

- Give me 3 numbers and I will tell you if they obey the rule
- Can you describe the rule or do you want to test another sequence?

Cognitive Biases

- **Confirmation bias**
  - Focusing attention on evidence that confirms your beliefs
- **Sunk costs**
  - Making a decision based on past investments, not future returns
- **Escalation of commitment**
  - Continuing to invest in a suboptimal choice



Quiz!

1,879 x 79 = ?

1,479,512

87 x 79 = ?

6,873

Errors in forecasting

- **Anchor and adjust**
  - We tend to anchor on the first piece of information and adjust

University of Missouri

Developed by Michael C. Runge

Quiz

Which of these is more common?

A) People getting the stomach flu each year

B) People getting food poisoning each year

On average, more people per year get food poising vs the flu (Piedmont healthcare)

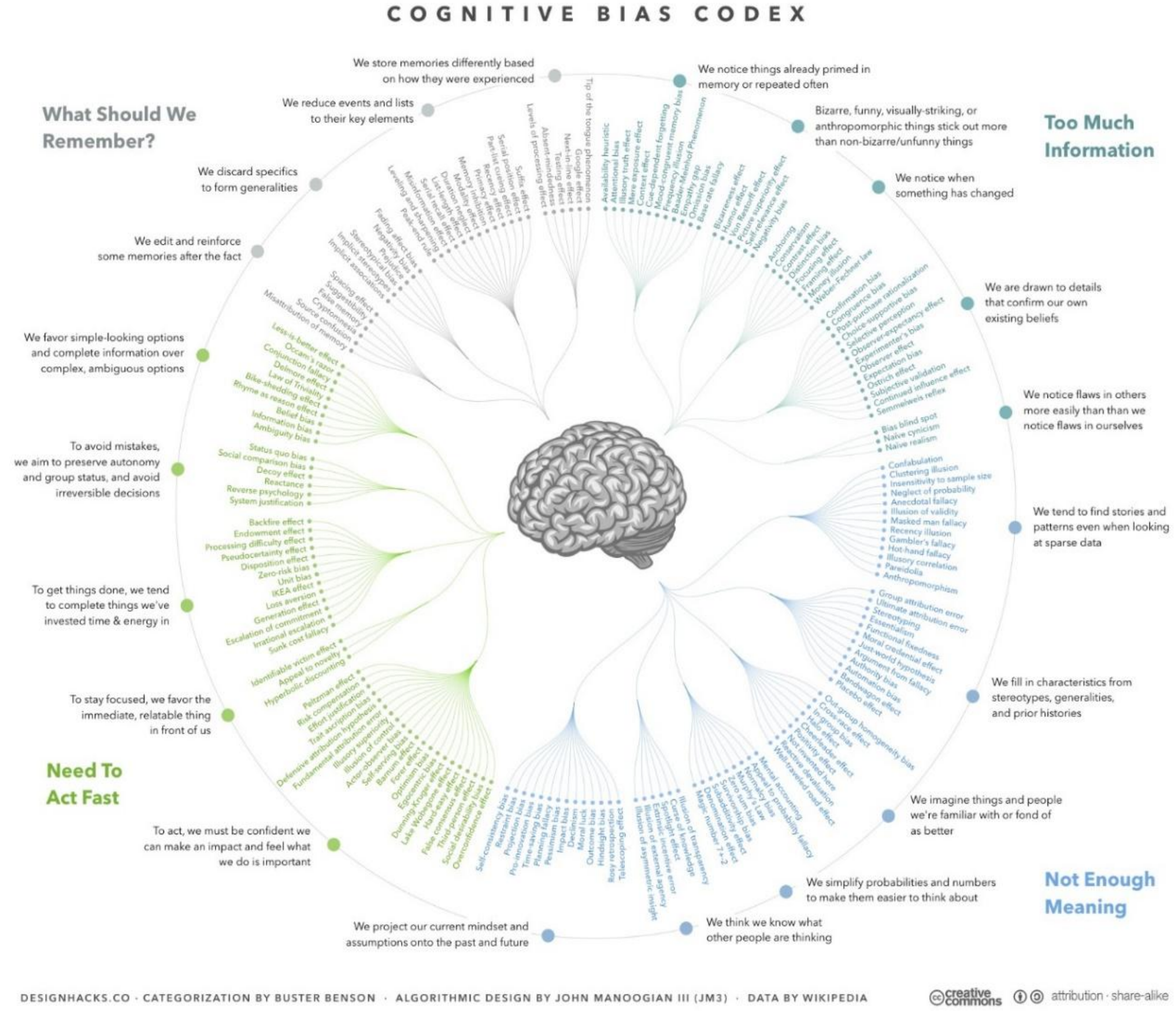
Errors in forecasting

- **Anchor and adjust**
  - We tend to anchor on the first piece of information and adjust
- **Availability heuristic**
  - Judge the probability of events by the ease of recall
- **Representativeness heuristic**
  - Judge the probability of an event by the extent to which it resembles a typical case

Scribbr

University of Missouri

Cognitive Biases



Developed by Michael C. Runge

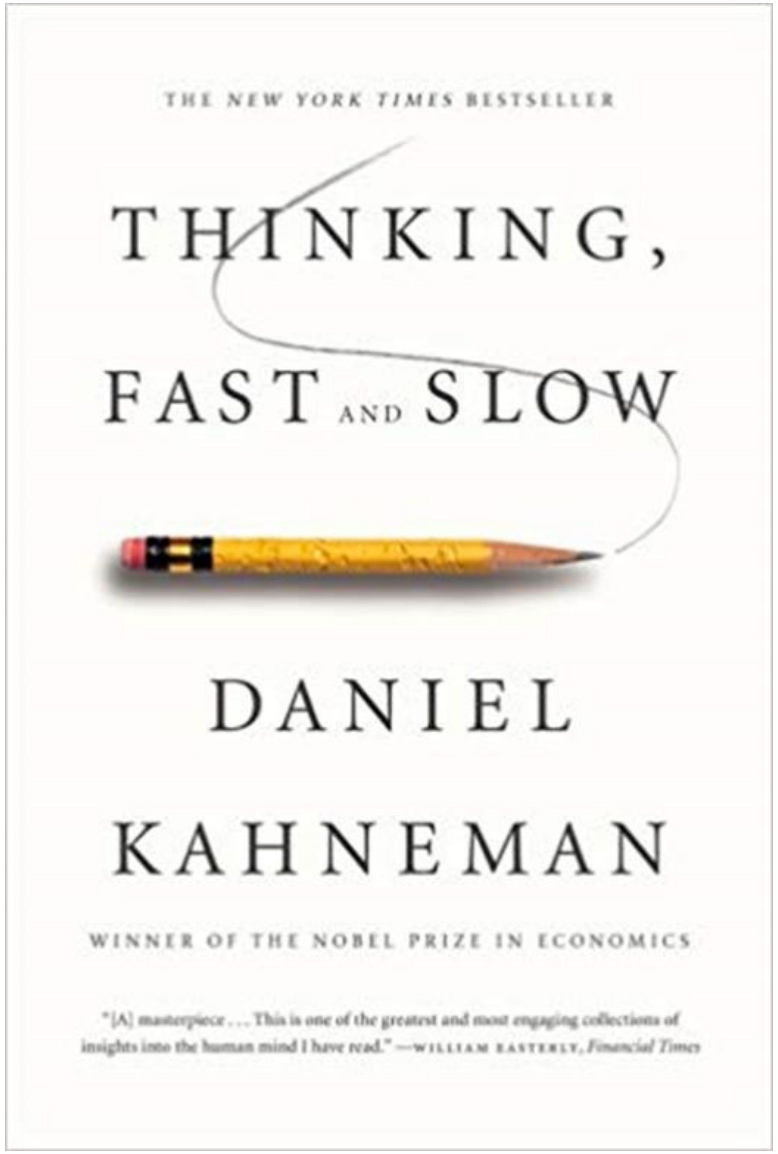
University of Missouri

Humans are both

GOOD and BAD decision makers

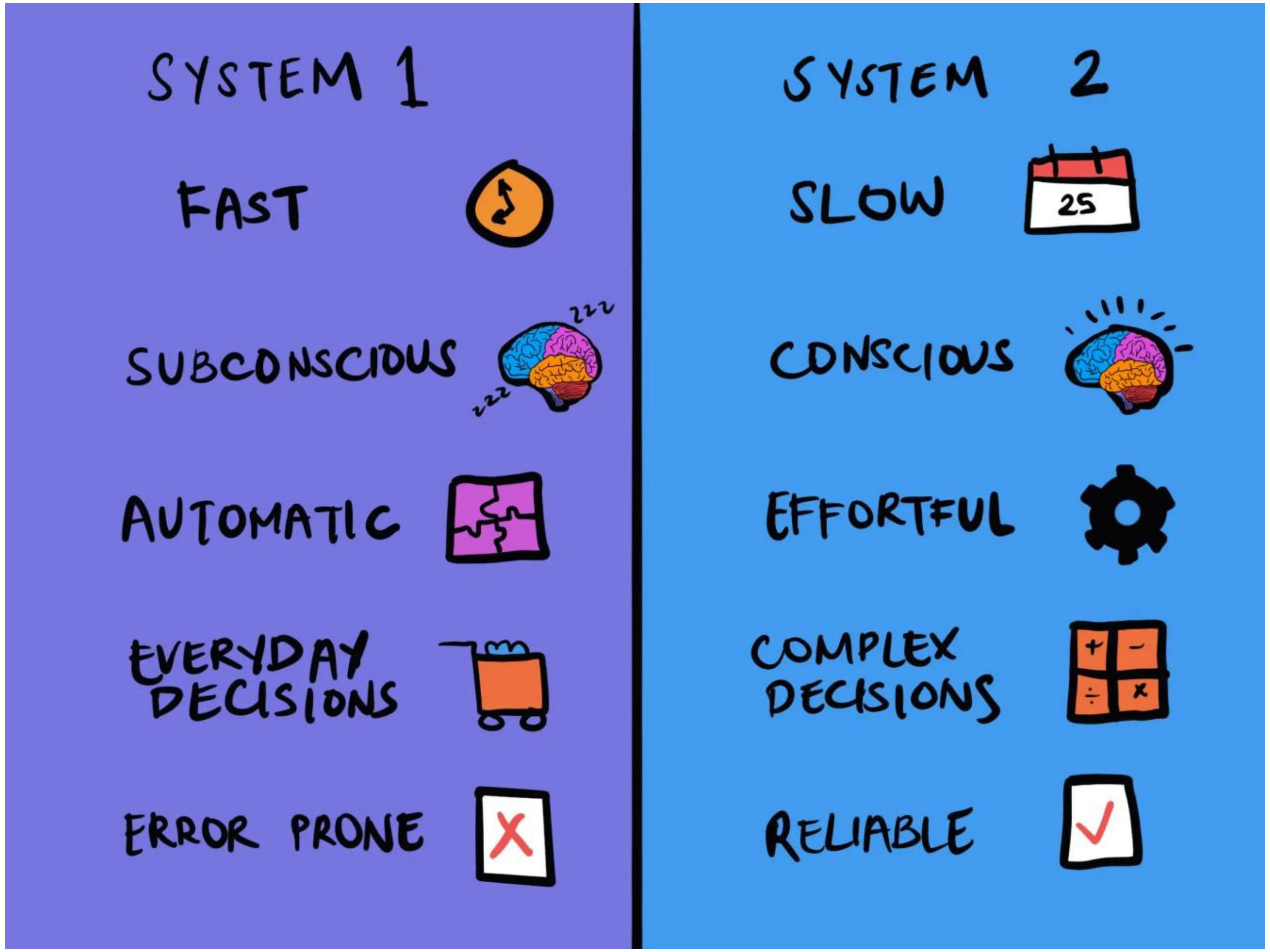
Human Decision Making

- **Daniel Kahneman** won the 2002 Nobel Prize in Economics for work he did in partnership with Amos Tversky on how people make decisions



Systems 1 and 2

- Kahneman and Tversky postulated that we have two cognitive systems

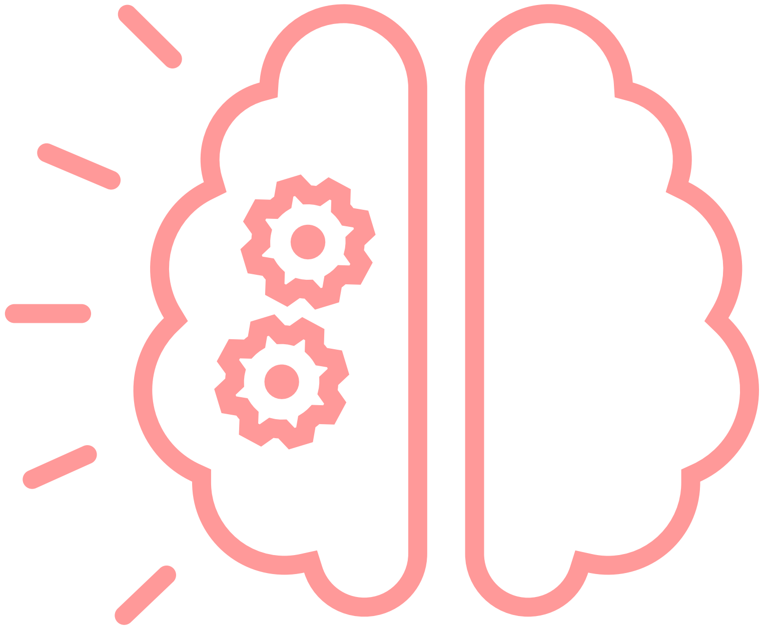


The Decision Lab

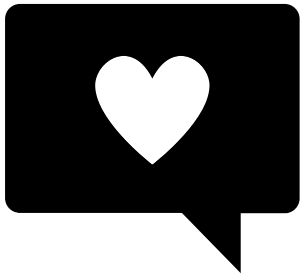
Structured Decision Making (SDM)

- Leverages our system 2 brain

- Decision Analysis/SDM is:
  “a formalization of common sense for decision problems which are too complex for informal use of common sense.”
  - Decision analysis and Structured Decision Making (SDM) are synonymous

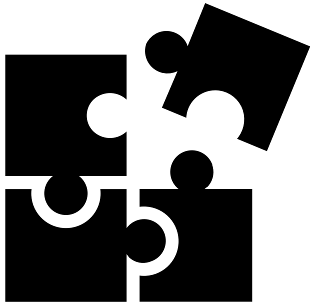


Two key elements of Structured Decision Making



1. Values-focused

- Objectives are discussed first
- Contrasts with alternative-focused methods

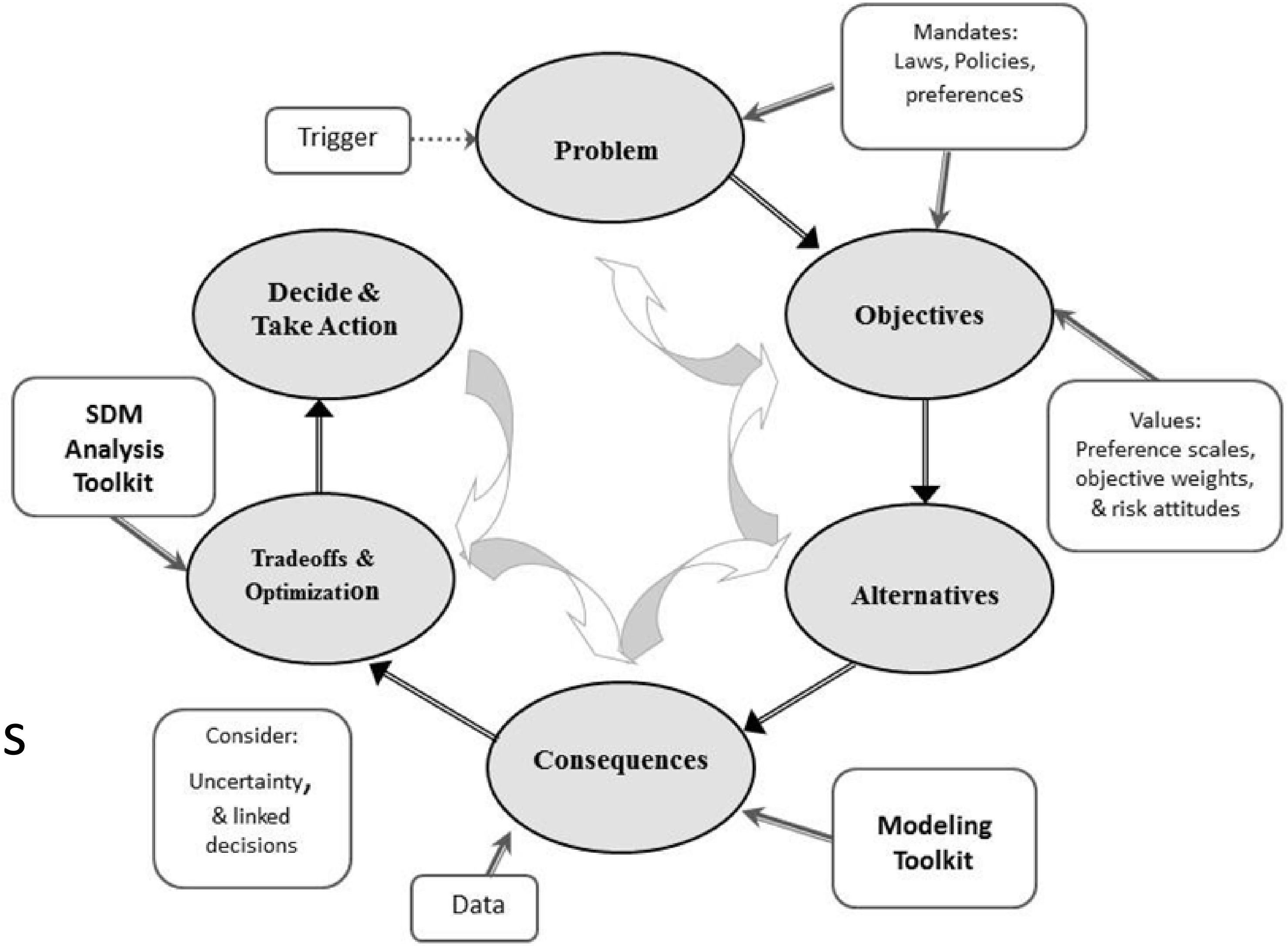


2. Problem decomposition

- Break problem into components, separating science from values
- Complete relevant analysis
- Recompose the parts to make a decision
- PrOACT

PrOACT

- Define the **Problem**
- Determine the **Objectives**
- Identify **Alternatives**
- Forecast the **Consequences**
- Evaluate the **Trade-offs**



Source: Jean Fitts Cochrane

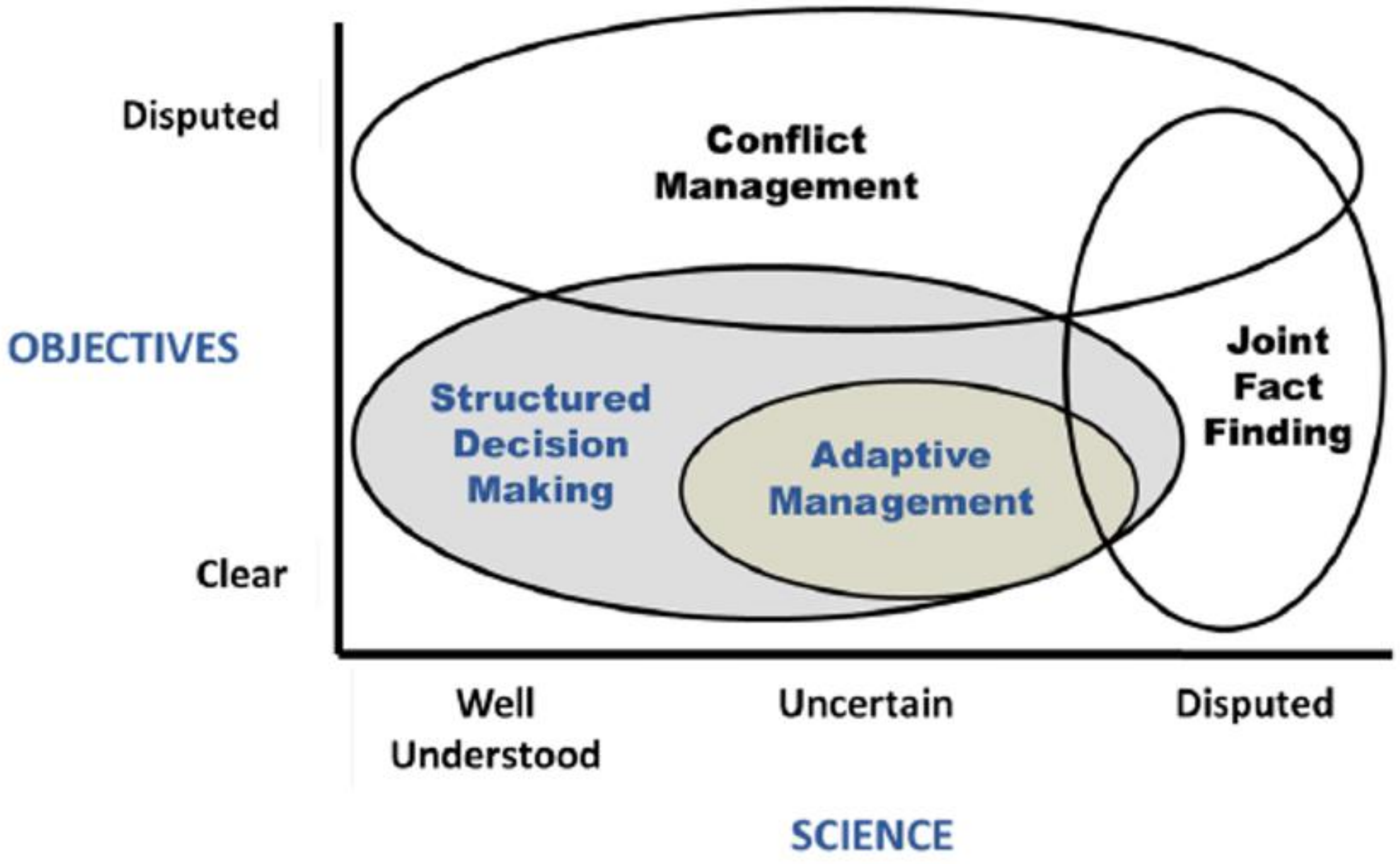
Additional steps

- Return to previous stages
- Sensitivity analysis
- Make the decision
  and monitor the outcome

Developed by Michael C. Runge

When is SDM appropriate?

- Single decision-making body



(From Runge et al. 2013)

Creative Commons Licenses photos

SDM examples- natural resources

Waterfowl harvests
(Williams and Johnson 1995)

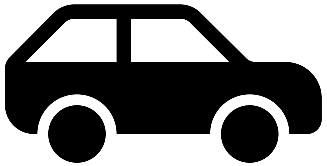
Whooping crane management
(Moore et al. 2008)

Bighorn Sheep disease mitigation
(Sells et al. 2016)

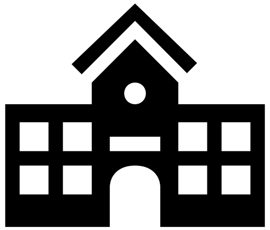
Bull trout reintroduction
(Brignon et al. 2017)

Dreissenid mussel management
(Sepulveda et al. 2022)

SDM examples- beyond natural resources



Buying a car



Choosing a college

Career decisions

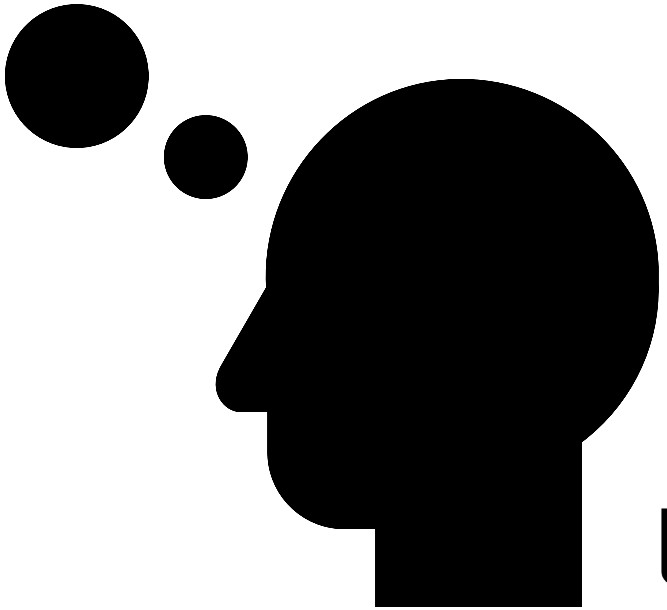
Buying a house

Developed by Brielle K Thompson

Creative Commons Licenses photos

Discussion:

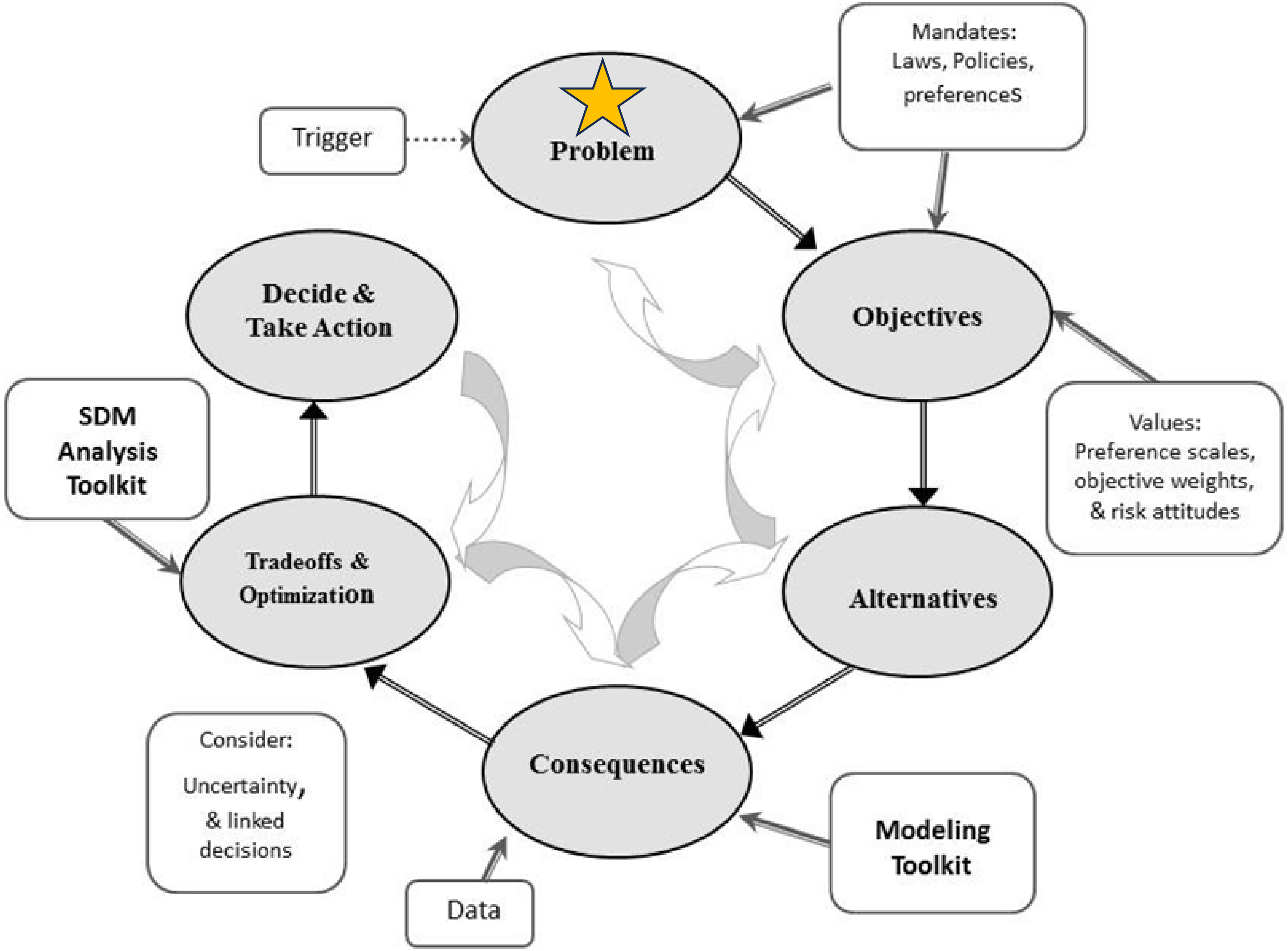
What makes a good decision?



Developed by Michael C. Runge

University of Missouri

Problem Framing



Source: Jean Fitts Cochrane

University of Missouri

Problem framing

- First and most important task in SDM
- Provides an *a priori*, explicit, and shared understanding of the problem
  - Making **decisions** is the **problem**
- Sets bounds on the problem by identifying spatial, temporal, organizational, legal, and other relevant bounds

"A good solution to a well-posed decision problem is almost always a smarter choice than an excellent solution to a poorly posed one."
~ Hammond et al.

Developed by Justin Gude, Angela Romito, Mike Runge

Common errors:

- Decision makers naturally jump to thinking about alternatives

Alternative focused thinking → Narrow problem framing → Omission of important objectives

- We assume the problem has defined itself. So, we don't frame the problem or think about what we really want to achieve

- Incorrect problem framing means we are wasting effort solving the wrong problem

Developed by Justin Gude, Angela Romito, Mike Runge

Creative Commons Licenses photos

Incorrect problem framing:

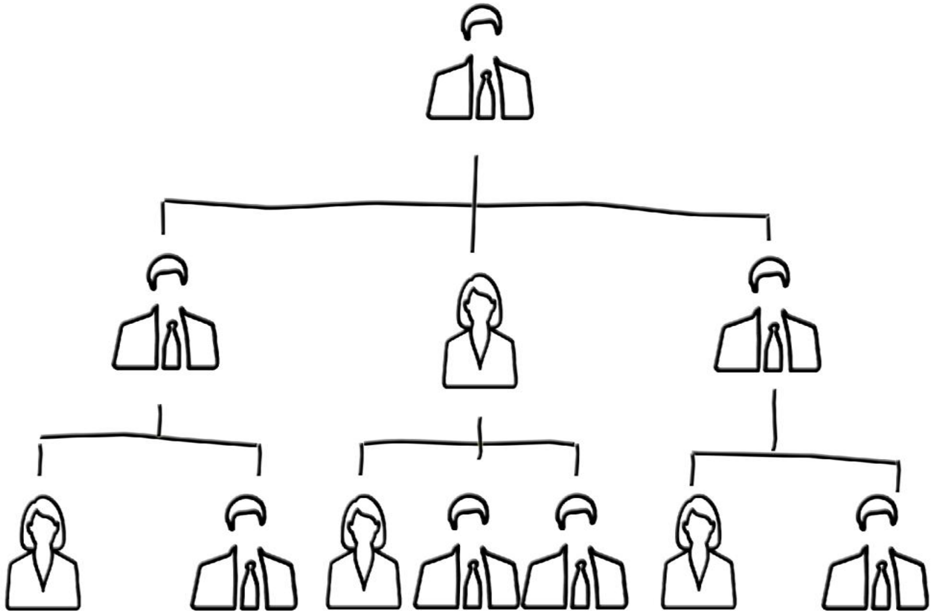
- *Prohibition in the US (1920-1933)*
  - **Government framing:** “How can we eliminate the negative effects of alcohol on society, such as crime, poverty, and health issues?
    - →18th amendment/Volstead Act banned alcohol
    - →Bootlegging, organized crime
  - **Hindsight reframing:** “How can we reduce the harmful effects of alcohol on society through education, regulation, and addressing the social factors that contribute to addiction?”

Creative Commons Licenses photos

Elements of problem framing:

1. ID the decision maker(s)

- **Who has the authority to commit to action?**
  - Can be surprisingly difficult/complex!
- **Some scenarios**
  - Single decision-maker
  - Multiple decision-makers
    - Willing to work together for joint aims
    - Competing with each other (not SDM)
  - Delegated authority
    - E.g., Governor → Director→ Administrator
- **Failure to ID & include all DMs in the process will make things difficult and confusing**



University of Missouri

Developed by Justin Gude, Angela Romito, Mike Runge

Creative Commons Licenses photos

Elements of problem framing:

2. ID other key players

- Decision Implementers
- Stakeholders/ **interest groups**
- The public
- Technical advisors

Interest group analysis

- Who has the ability to influence the decision?
- Who is influenced by the decision?

Creative Commons Licenses photos

Elements of problem framing:

3. Consider the legal and regulatory context

- Particularly for decisions by public agencies
- What laws confer authority for the decision?
- How does the legislation or associated regulations bound the decision problems?

- Example: USFWS is the decision maker and must follow Migratory Bird Treaty Act regulations

Developed by Justin Gude, Angela Romito, Mike Runge

Elements of problem framing:

Creative Commons Licenses photos

4. Consider the decision structure

Frequency & Timing - How often? When? Are other decisions linked?

Scope - How large, broad, complicated is the decision?

Objectives –What are the desired outcomes?

Actions – What kinds of alternatives are being chosen from?

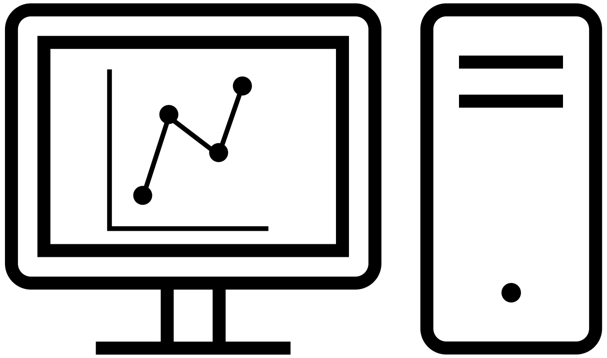
Constraints - Legal, financial, political, perceived or real constraints?

Uncertainty - What degree of uncertainty is present? Can it be ignored?

Elements of problem framing:

5. Consider the type of analysis required

- How much detail is needed?
- Do the data and analytical methods exist?
- Do you have access to the expertise?
- Is uncertainty an impediment?



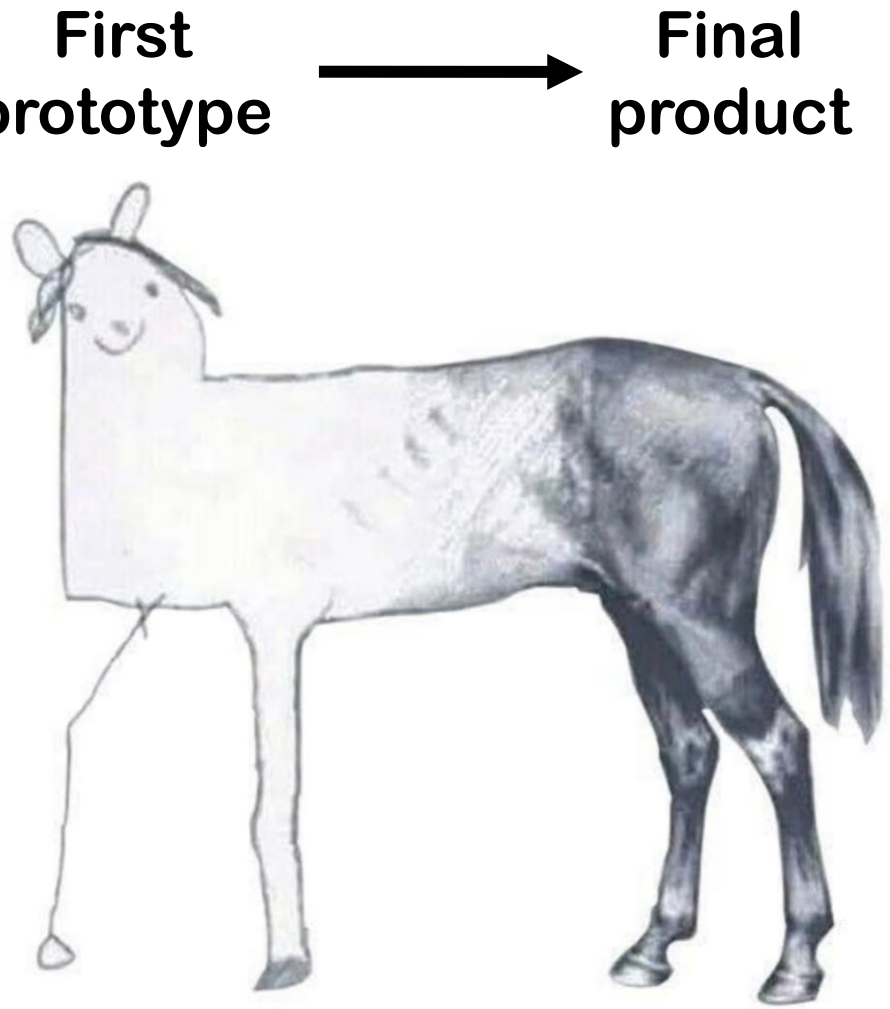
Developed by Justin Gude, Angela Romito, Mike Runge

Elements of problem framing:

6. Revise as needed

- The problem statement is likely to change as development proceeds
- Adopt iterative/ **rapid prototyping** as an approach

"Good enough for now, safe enough to try"



Developed by Justin Gude, Angela Romito, Mike Runge

Problem framing: problem statement

- About a paragraph long (or sometimes a very long, run-on sentence)
- Captures the essential outline of the problem
- Helps participants focus
- Limits objectives and alternatives to those relevant to the problem

Developed by Justin Gude, Angela Romito, Mike Runge

Problem framing: prompts

- **Decision Maker** – Who will make the decision?
- **Trigger** – Why does a decision need to be made? Why does it matter?
- **Action** – What is the decision? What action needs to be taken?
- **Constraints** – legal, financial, political? Are these perceived or real?
- **Frequency and Timing** – Periodicity of decision. Are other decisions linked to this one?
- **Scope** – How broad or complicated is the decision?

Example:

Jean Fitts Cochrane, Angela Matz, Mitch Eaton –SDM workshop

[1] What is the decision—what kind of action needs to be taken?
[2] What triggered this decision; why does it matter?
[3] What are the legal context and constraints?
[4] Who is the decision maker?
[5] What is the decision timing and frequency; are other decisions linked?
[6] What is the scope of the problem (how broad or complicated is it)?

[1] A revised program of vegetation treatment needs to be implemented for Rolling Thunder NWR that achieves recovery goals for protected prairie-endemic species. [2] Recently, refuge conservation objectives expanded to include sustaining newly listed butterfly and beetle populations. These species may be harmed by some grassland management practices, particularly prescribed burning that has been used for 25 years to control woody species invasion and benefit rare plant populations. [3] The new program will become part of a multi-species recovery plan to meet ESA requirements, and will also have to comply with the NWR Administration Act and NEPA. Management options may be constrained by nearby residential development and local opposition to prescribed fires; also local ranchers expect economic benefits from grazing cattle on the refuge. [4] The refuge manager must decide on a treatment program, in consultation with the species recovery team. [5] The program must be in place by the summer and will last for five years. Some of the treatments may restrict future management options for up to 10 years, because of infrastructure commitments and ecological effects. [6] While the vegetation management strategy technically only applies to grasslands on about half of this refuge for a five-year program, the decision is considered critical for sustaining these endemic prairie species throughout their limited ranges

The equation for problem framing

Using the following template:

"Decision Maker (**D**) is trying to do **X** to achieve **Y** over time **Z** and in place **W** considering **B**."

where,

D = the Decision maker(s)

X = the type(s) of action that needs to be taken

Y = the ultimate goal(s) to be achieved by "X"

Z = the temporal extent of the decision problem.

W = the spatial extent of the decision problem

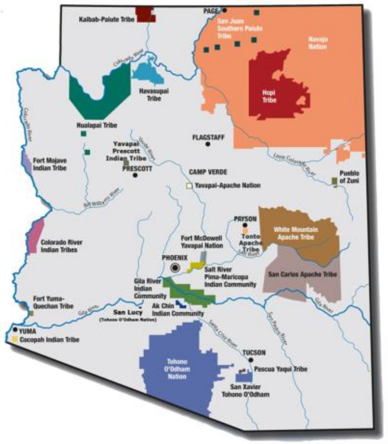
B = potential constraints (legal, financial, and political) and important uncertainties (scientific or other)

Developed by Justin Gude, Angela Romito, Mike Runge

Creative Commons Licenses photos

Case study: (Runge et al. 2011)

Arizona Department of Education

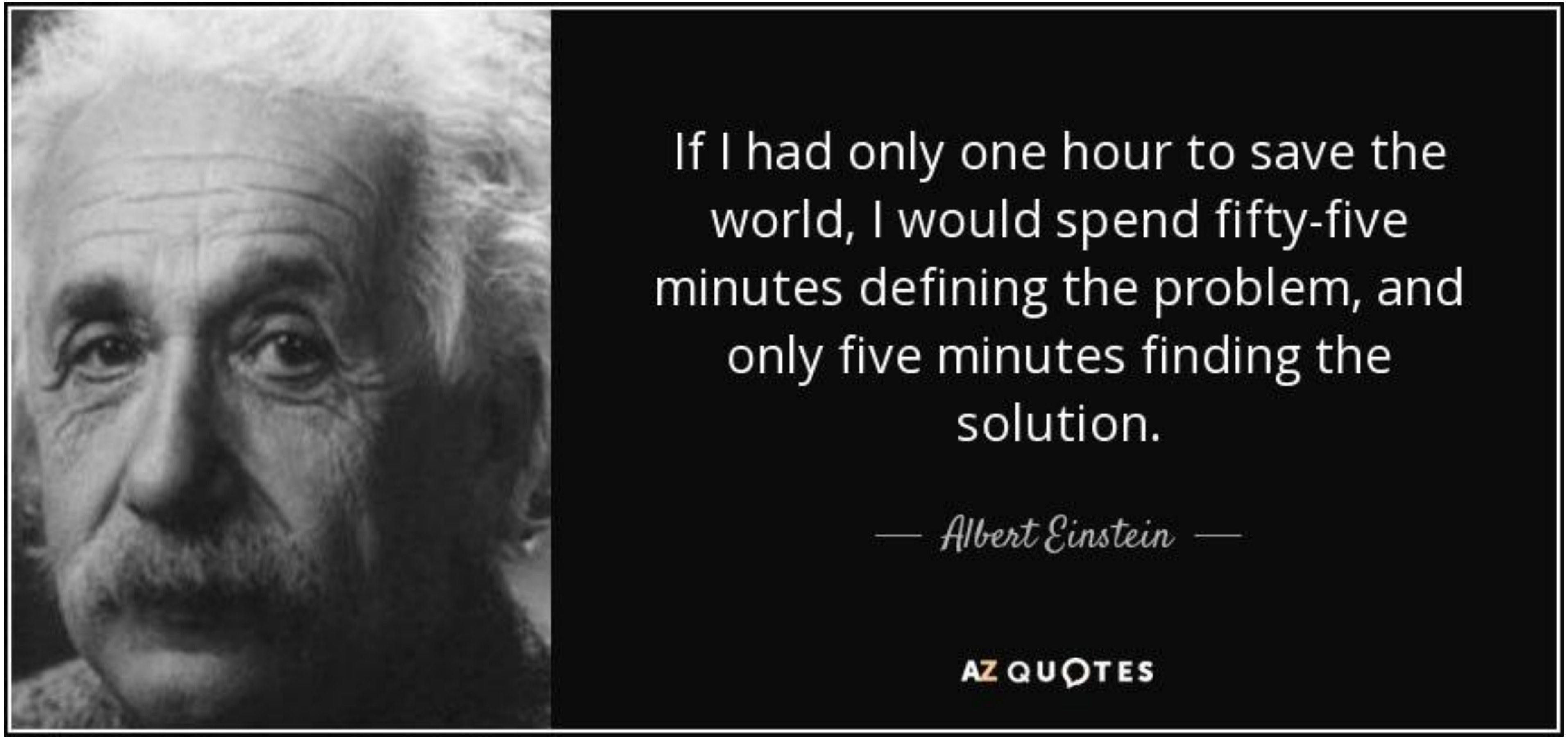
Brief **problem statement:** *"Decision Maker (D) is trying to do X to achieve Y over time Z and in place W considering B."*

Bureau of reclamation is trying to **make decisions regarding invasive trout management** to **achieve recovery of humpback chub** populations **over the next 5 years** in the **Little Colorado River, below the Glen Canyon** Dam considering **sacred sites and spiritual values of local Native American tribes (e.g., avoid taking of life), humpback chub recovery, trout invasion, recreational values, cost, and local economies.**

Adapted, modified, and simplified from Runge et al. 2011

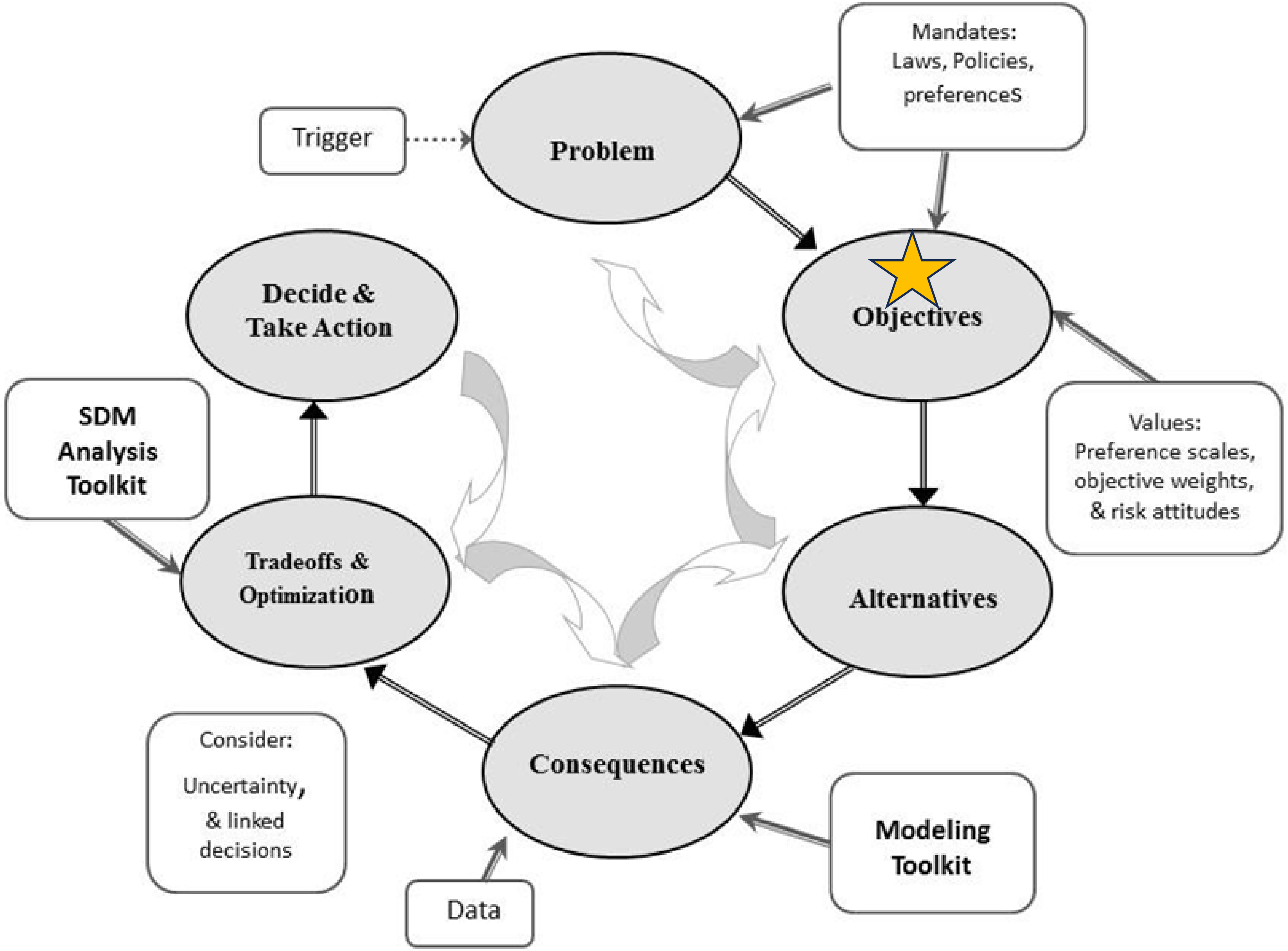
Problem framing is hard!

- It’s worth taking the time to get it right…



University of Missouri

Objectives



Source: Jean Fitts Cochrane

What are objectives, and why are they important?

- We make decisions to achieve something
- Objectives are what we want to achieve

Medium

Example: I am deciding where to go on vacation.
What objectives are in play for me?

I want to maximize:
- Relaxation
- Fun
- Comfort

I want to minimize:
- Cost
- Travel time

Developed by Alex McInturff, Jean Fitts Cochrane, Angela Matz, Jennifer A. Szymanski, James E. Lyons, Sarah J. Converse, & Michael C. Runge

University of Missouri

What are objectives, and why are they important?

- Spending time on this step is important because we will:
  - Compare alternatives on the right criteria
  - Develop creative alternatives
  - Know what we want to make predictions about
  - Better explain our decisions

Medium

We are surprisingly poor at identifying objectives

1) We often don't know all our objectives:
- Bond et al. (2008) asked MBA students to imagine choosing an MBA program, list their objectives, then check against a master list
    - 4/10 of the final top 10 objectives were absent from the student's first list

Medium

We are surprisingly poor at identifying objectives

1) We often don’t know all our objectives
2) We confuse ends and means:
   - Example – when deciding about management of an endangered species:
     - Is this the objective?
       - Maximize survival probability of the endangered species
     - Or is this the objective?
       - Maximize probability of persistence of the endangered species

Medium

Pieces of an objective:

Direction (maximize, minimize) ↑ ↓ **+** **What is desired** ♥ **+** **Attribute** (the units) e.g. $

Process for identifying objectives:

1. Articulate concerns and convert to objectives

Ask:

- What do you hope to achieve?
- What concerns will this decision address?
- How can the current situation be improved?
- What are the best and worst possible outcomes from this decision?

Make these concerns – and subsequent objectives – distinct and independent

1. Articulate concerns and convert to objectives

Convert concerns to objectives:

Hint: direction + what is desired (don't worry about units yet!)

Goal or Concern	***Hope to Achieve***	***Potential Objective***
It's hard to catch bluegills any more	Improve fishing	
Many loons die ingesting lead tackle	Reduce loon mortality and increase loon populations	
Ballast water brings invasive species	Avoid release of invasive species and protect native species	
Certain interest groups feel excluded	Organize an inclusive decision process	
I won't have enough money for this	Reduce cost and manage within budget	

1. Articulate concerns and convert to objectives

Convert concerns to objectives:

Hint: direction + what is desired (don't worry about units yet!)

Goal or Concern	***Hope to Achieve***	***Potential Objective***
It's hard to catch bluegills any more	Improve fishing	Maximize recreational fishing success
Many loons die ingesting lead tackle	Reduce loon mortality and increase loon populations	Maximize persistence of loon populations
Ballast water brings invasive species	Avoid release of invasive species and protect native species	Maximize native invertebrate and fish communities in lakes
Certain interest groups feel excluded	Organize an inclusive decision process	Maximize interest group engagement
I won't have enough money for this	Reduce cost and manage within budget	Minimize cost

2a. Distinguish types of objectives

1. **Fundamental**
   - The basic reason for caring about the decision (essential)
2. **Means**
   - Influence the achievement of fundamental objectives (not necessarily essential)
3. **Process**
   - Concern for how the decision is made rather than what decision is made
     - Example- maximize public trust
4. **Strategic**
   - Higher level – objectives covering all decisions made by the organization or person or an agency mandate

2a. Distinguish types of objectives

Ask
“WHY”

Fundamental

When the answer is:
“Just because”/ “Inherent value”

Ask
“HOW”

Means

When the answer is:
This is how we address our fundamental concern. Or…
this is how we measure success

Often outputs of models

University of Missouri

2a. Distinguish types of objectives

Exercise: Identify the fundamental objective

Concern	**Objectives**
1. Ballast water brings invasive species	Minimize ballast dumping
	Minimize invasive species introductions
	Maximize native species
2. You don't have enough money for this	Minimize cost
	Maximize conservation within budget

2a. Distinguish types of objectives

Exercise: Identify the fundamental objective ★

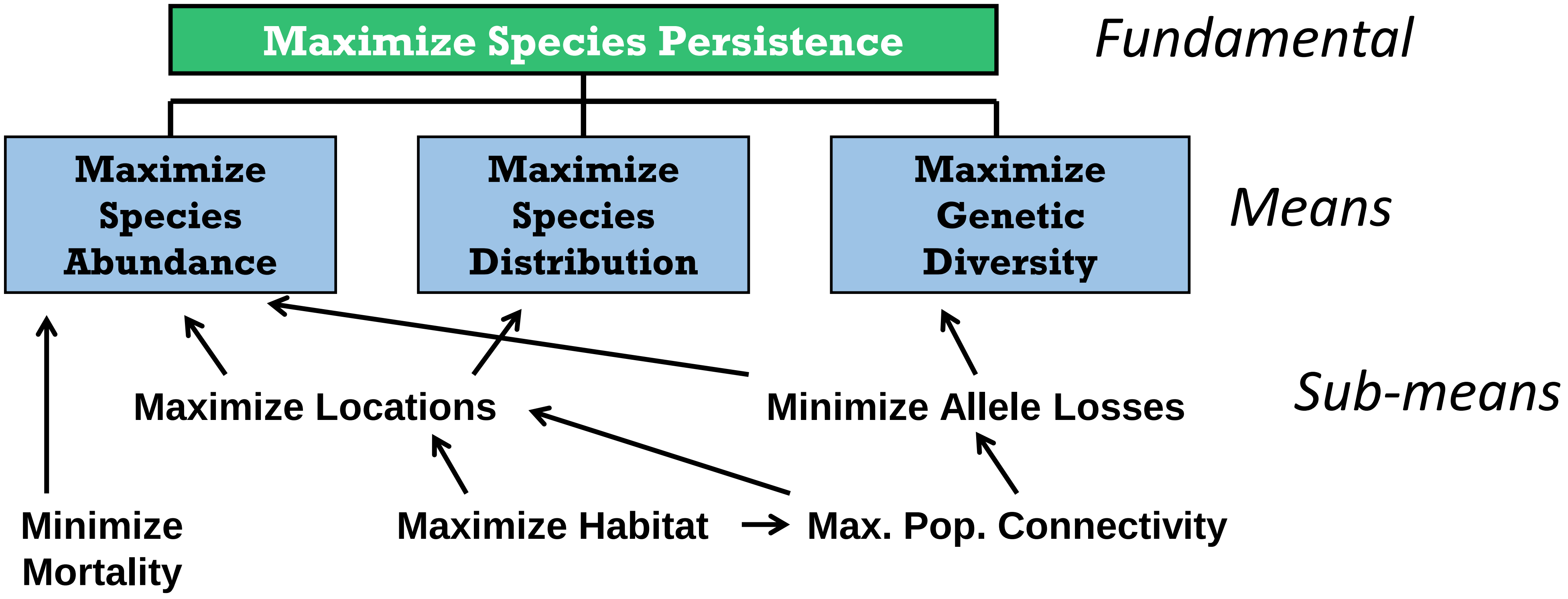
Concern	Objectives
1. Ballast water brings invasive species	Minimize ballast dumping
	Minimize invasive species introductions
	Maximize native species ★
2. You don't have enough money for this	Minimize cost ★
	Maximize conservation ~~within budget~~

Do not combine objectives!

Developed by Alex McInturff, Jean Fitts Cochrane, Angela Matz, Jennifer A. Szymanski, James E. Lyons, Sarah J. Converse, & Michael C. Runge

University of Missouri

2b. Create an objective hierarchy



Developed by Alex McInturff, Jean Fitts Cochrane, Angela Matz, Jennifer A. Szymanski, James E. Lyons, Sarah J. Converse, & Michael C. Runge

3. Develop measurable attributes (the units)

Attributes measure performance and is used to:

- Predict (in advance of the decision) how a given decision will lead to measurable outcomes
- Compare realized objective outcomes to predicted outcomes after decision implementation

Attribute scales:

1. Natural scale

- Objective can be directly measured
- Example: $ for cost

2. Constructed scale

- Sliding or relative scale requiring interpretation
- Example: Likert scale (5 = very satisfied…1 = very unsatisfied) *for* fisher satisfaction

3. Proxy scale

- Natural attribute that is highly correlated with the objective, but does not directly measure
- Example: % of natural range preserved *for* species genetic diversity

3. Develop measurable attributes (the units)

Example

Objective	Direction	Attribute	
Minimize costs	Minimize (↓)	M$/yr	Natural
Maximize occupancy probability	Maximize (↑)	Probability (0-1)	Natural
Minimize extinction probability	Minimize (↓)	Probability (0-1)	Natural
Maximize hunter satisfaction	Maximize (↑)	Harvest Success Rate (# harvested/# permits)	Proxy

Exercise: What are the attribute types?

Protect and preserve hemlock

- **Hemlock stand health**
  - Minimize: (% of mortality & defoliation)
    1 = <10 & <10
    2 = <10 & 11-20
    3 = 11-25 & 21-50
    4 = >25 & >50
  - *Constructed*
- **Stand size**
  - Maximize: Stand acres
  - *Natural*
- **Hemlock component of stand**
  - Maximize: % of hemlock overstory
  - *Natural*
- **Stand structure**
  - Minimize: % of understory
  - *Proxy*

Adapted from Blomquist et al. (2010)

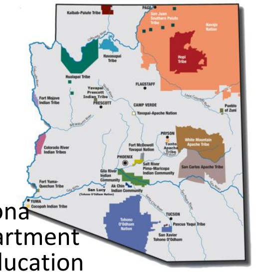
University of Missouri

Developed by Alex McInturff, Jean Fitts Cochrane, Angela Matz, Jennifer A. Szymanski, James E. Lyons, Sarah J. Converse, & Michael C. Runge

Creative Commons Licenses photos

Case study: (Runge et al. 2011)



Arizona Department of Education

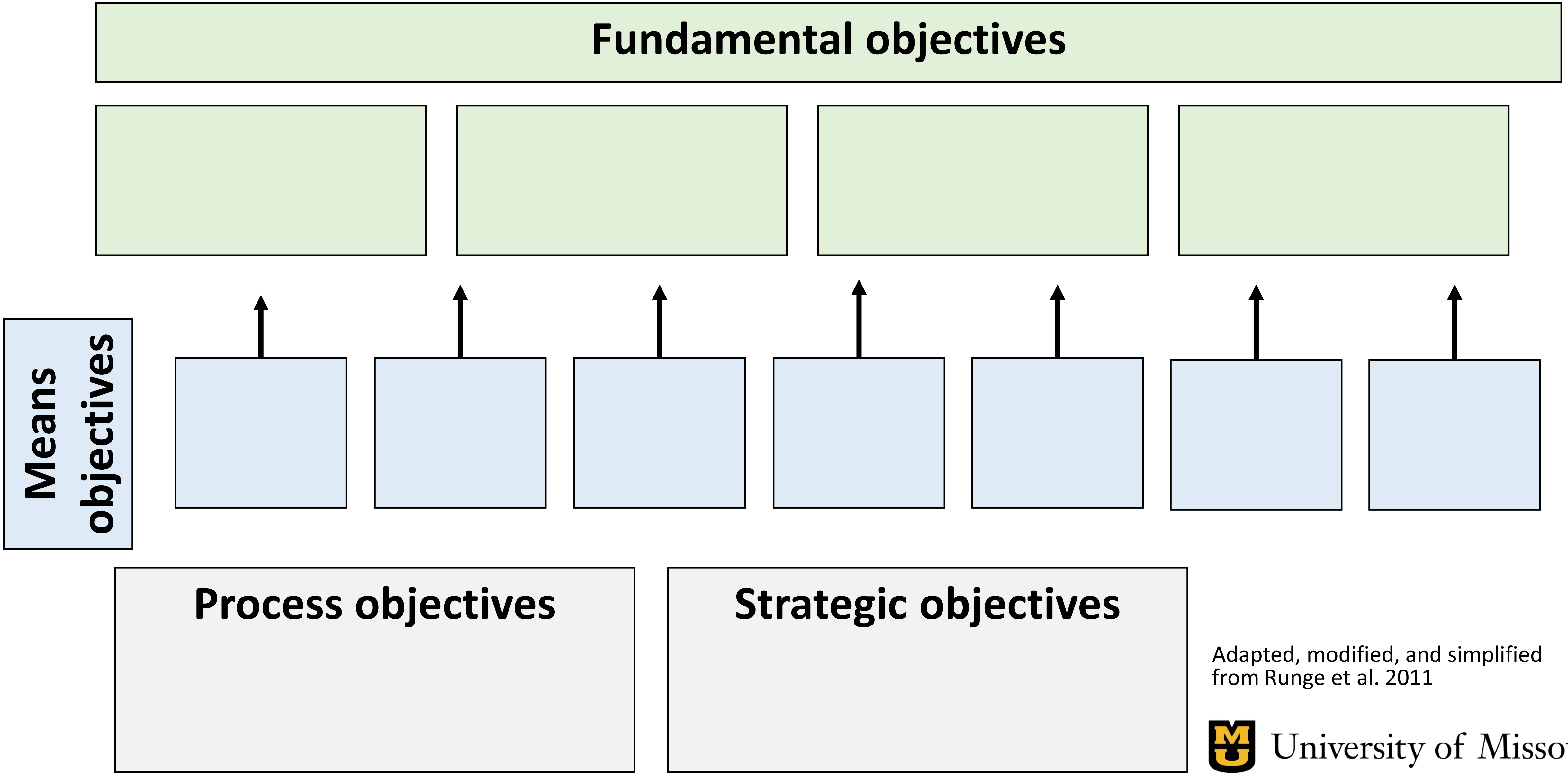
Brief **problem statement:** *"Decision Maker (D) is trying to do X to achieve Y over time Z and in place W considering B."*

Bureau of reclamation is trying to **make decisions regarding invasive trout management** to **achieve recovery of humpback chub** populations **over the next 5 years** in the **Little Colorado River, below the Glen Canyon** Dam considering **sacred sites and spiritual values of local Native American tribes (e.g., avoid taking of life), humpback chub recovery, trout invasion, recreational values, cost, and local economies.**

Adapted, modified, and simplified from Runge et al. 2011

Your task: Articulate objectives
(objectives hierarchy- fundamental, means, process, strategic objectives?)

Your task: Articulate objectives (objectives hierarchy)



Adapted, modified, and simplified from Runge et al. 2011

University of Missouri

Your task: Articulate objectives (objectives hierarchy)

Fundamental objectives

- Maximize resources to protect tribal sacred sites and spiritual values
- Maximize native species integrity
- Maximize recreation
- Minimize cost

Means objectives

- Minimize taking of life
- Maximize HBC population
- Min. trout population
- Min. wilderness days lost
- Max. fish catch
- Min. trout removal cost
- Max. dam power production

Process objectives

- Be respectful of tribal values and rituals

Strategic objectives

-Operate within the authority, capabilities, and legal responsibility of the Bureau of Reclamation

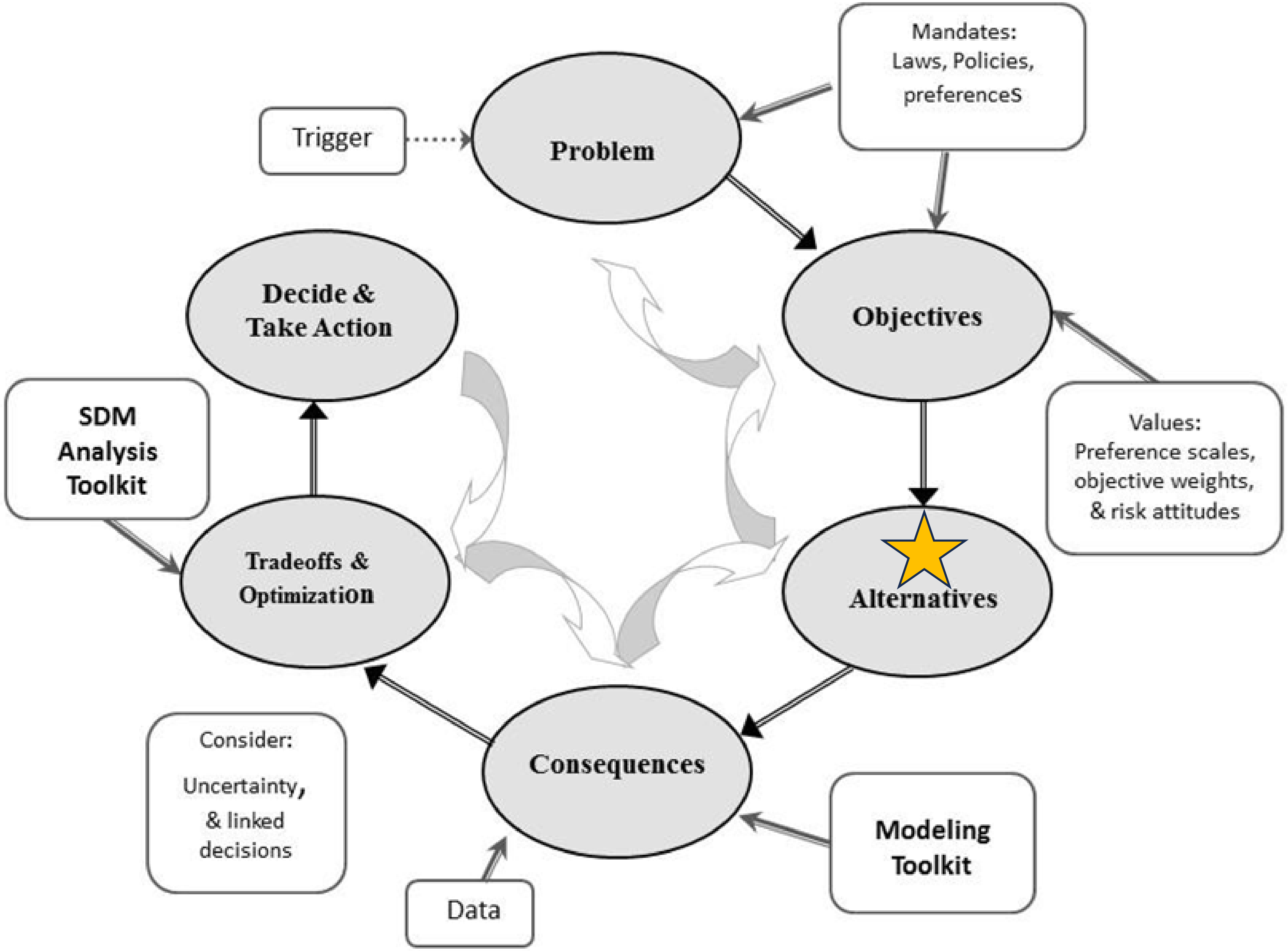
- Follow ESA compliances

Adapted, modified, and simplified from Runge et al. 2011

University of Missouri

5 minute break!!

Alternatives



Source: Jean Fitts Cochrane

Creative Commons Licenses photos

Importance of good alternatives

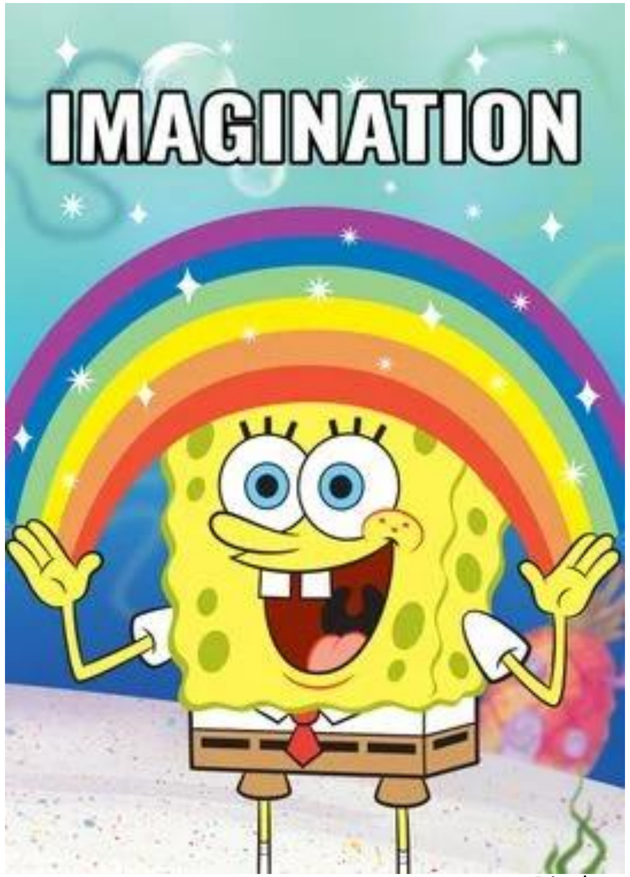
- A good alternative is one that provides a good chance of achieving objectives
- Good alternatives are:
  - Values-focused
  - Fully specified
  - Internally coherent
  - Distinct

University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Good alternatives require

- **Imagination**
  - Beware of the tendency to limit our ideas to what are thought to be ‘practical’ alternatives
- **Creativity**
  - Think of the widest range of possible alternatives
  - Don’t let preconceived ideas or constraints be limiting



Displate

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Creative Commons Licenses photos

University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Challenges to identifying alternatives

- Falling prey to cognitive biases (e.g., status quo bias)
- Accepting real or perceived constraints
- Evaluating alternatives prematurely

Tenor

Suggestions to identify alternatives

1. Focus on fundamental objectives and address conflicting objectives

- Create alternatives to achieve the best possible consequences for each fundamental objective, one at a time.

- Then, create hybrid alternatives to satisfy more than one objective. Include conflicting objectives.

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Creative Commons Licenses photos

Suggestions to identify alternatives

1. Focus on fundamental objectives and address conflicting objectives

Example: Rare Snakes

- Problem/concern:
  - Many rare snakes are killed during capture
- Objectives:
  - Minimize capture mortality
  - Maximize pet industry

Potentially conflicting!!

- Alternatives:
  - Status quo – do nothing
  - Ban sale of snakes
  - Others?

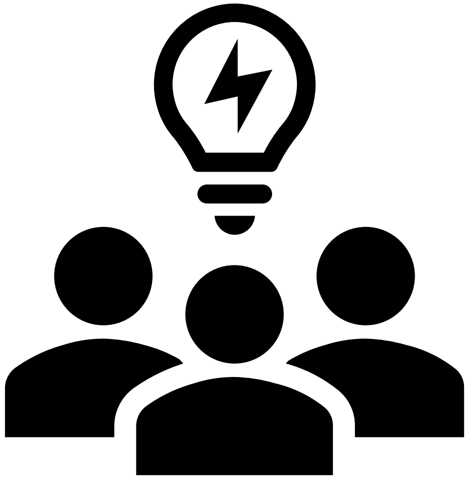
University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Suggestions to identify alternatives
2. Challenge constraints

Tips:

- Distinguish real and perceived constraints
- Don't anchor on initial set of options
- Don't evaluate – just develop
- Give people time and permission to be creative



University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Creative Commons Licenses photos

Suggestions to identify alternatives

2. Challenge constraints

Example: Bird translocation

Which of several islands should an endangered bird be translocated?

- Perceived constraint: Introduced predators on Island A make it unsuitable

- What are some creative alternatives?

University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Suggestions to identify alternatives

3. Create groups of alternatives

- Groups of alternatives includes portfolios and strategies

JARGON ALLERT!!

- **Alternatives** = general term for complete, comparable solutions to a decision problem
- **Actions** = alternatives formed by individual options
- **Strategies and Portfolios** = alternatives formed by combinations of actions

University of Missouri

Suggestions to identify alternatives

3a. Creating portfolios

- Portfolio: a combination of **like** elements arranged in a set
- The elements themselves can be actions
  - e.g., set of research projects, funding allocation
- The combination now represents a single alternative
  - e.g., stock portfolio
- Constraints often limit number of possible portfolios
  - e.g., total budget for allocation across projects

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Suggestions to identify alternatives

3a. Creating portfolios

Example: portfolios for invasive species removal

Alternatives

Target species to remove
A
B
C
D
A+B
…
B+C+D
A+B+C+D

Combination of like elements

University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Suggestions to identify alternatives

3a. Creating <u>**strategies**</u>

- Strategy: alternative **c**ombining multiple **unlike** elements:
- Strategy table:
  1) Group actions into themes (columns)
  2) Create distinct strategies that represent different approaches or emphasize different objectives
  3) Select the actions in each theme that fit each strategy
  4) Combine selected elements into a strategy
  5) Repeat steps 2-4 to create all strategies

University of Missouri

3b. Creating **strategies**

- Strategy table: Chipotle menu

Themes of ingredients:	*Meat*	*Rice, Beans, and Veggies*	*Top It Off*
	None	Brown rice	None
	Steak	White rice	Salsa (Mild)
	Carnitas	Black beans	Salsa (Hot)
	Chicken	Pinto beans	Sour cream
	Barbacoa	Fajita veggies	Tomatillo
			Chili-Corn salsa
			Lettuce
			Guacamole
			Cheese

3b. Creating **strategies**

- Strategy table: Chipotle menu

Themes of ingredients:	*Meat*	*Rice, Beans, and Veggies*	*Top It Off*
Strategies (aka burritos): **"Brielle's favorite"**	None Steak Carnitas **Chicken** Barbacoa	**Brown rice** White rice **Black beans** Pinto beans **Fajita veggies**	None **Salsa (Mild)** Salsa (Hot) Sour cream Tomatillo Chili-Corn salsa **Lettuce** **Guacamole** **Cheese**

3b. Creating <u>**strategies**</u>

- Strategy table: Chipotle menu

Themes of ingredients:	*Meat*	*Rice, Beans, and Veggies*	*Top It Off*
Strategies (aka burritos): <u>**"The Barnyard"**</u>	None <u>**Steak**</u> <u>**Carnitas**</u> <u>**Chicken**</u> Barbacoa	Brown rice <u>**White rice**</u> Black beans <u>**Pinto beans**</u> Fajita veggies	None Salsa (Mild) <u>**Salsa (Hot)**</u> Sour cream Tomatillo Chili-Corn salsa Lettuce Guacamole Cheese

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

3b. Creating **strategies**

- Strategy table: Chipotle menu

Themes of ingredients:	*Meat*	*Rice, Beans, and Veggies*	*Top It Off*
Strategies (aka burritos): **“The Veggie”**	**None** Steak Carnitas Chicken Barbacoa	**Brown rice** White rice **Black beans** **Pinto beans** **Fajita veggies**	None **Salsa (Mild)** Salsa (Hot) **Sour cream** Tomatillo **Chili-Corn salsa** **Lettuce** **Guacamole** **Cheese**

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

3b. Creating **strategies**

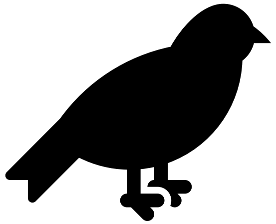
- **Final strategy table**: Chipotle menu

Themes→ ↓ Strategies	*Meat*	*Rice, Beans, and Veggies*	*Top It Off*
Brielle's Favorite	Chicken	Brown rice, Black beans, Veggies	Salsa (mild), Chili-corn, Lettuce, Guacamole, Cheese
The Barnyard	Steak, Carnitas, Chicken	White rice, Pinto beans	Salsa (hot), Cheese
The Veggie	None	Brown rice, Black beans, Pinto beans, Veggies	Salsa (mild), sour cream Chili-corn, Lettuce, Guacamole, Cheese

University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

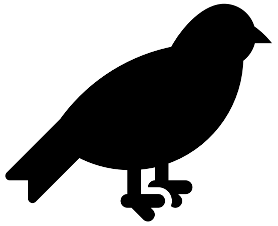
3b. Creating **strategies**



- Example: Threatened species recovery

Themes:	*Habitat Protection*	*Predator Control*	*Enhance Population*	*Alternative Economic Activity*
	Status Quo	Status Quo Harvest (5%)	None	None
	Ban logging in critical habitat	Increase harvest rate of predator to 10%	Maternity Pens	Promote sustainable harvest of species through lottery
	Develop linkage corridors	Increase harvest rate of predator to 50%	Captive Breeding	Promote non-consumptive recreation
			Translocate	

3b. Creating **strategies**



- **Final strategy table** for threatened species recovery,

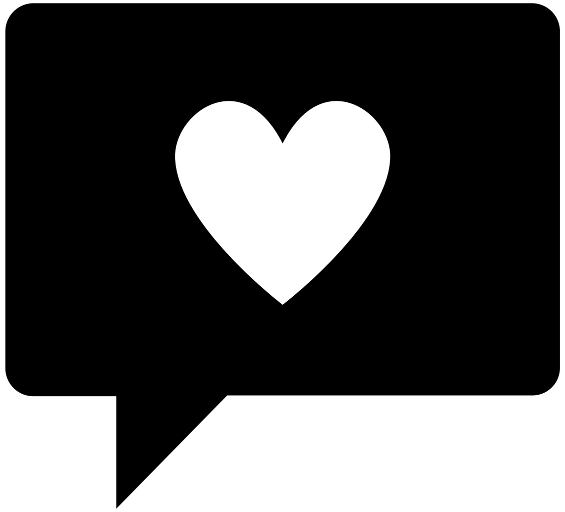
Themes→ ↓ Strategies	*Habitat Protection*	*Predator Control*	*Enhance Population*	*Alternative Economic Activity*
Status Quo	Status Quo	Status Quo Harvest (5%)	None	None
“On the Go” (Dispersal)	Develop linkage corridors	Increase harvest rate of BNEG to 10%	Translocate	Promote non-consumptive recreation
Increase Pop to Carrying Cap	Ban logging in critical habitat	Increase harvest rate of BNEG to 50%	Captive Breeding	Promote non-consumptive recreation

University of Missouri

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

4. Revisit objectives

- Once you generate initial set of alternatives:
  - Be sure you’ve properly separated fundamental from means objectives
  - Identify if additional objectives exist



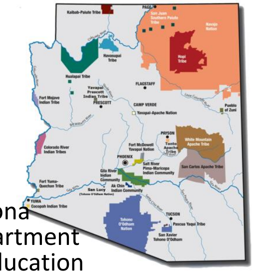
General tips:

- SDM is iterative, don't stop looking for alternatives
- Create first, evaluate later
- Consider alternatives that …
  - Are an ongoing process
  - Gather more information
- Treat 'unique' alternatives as real and subject to the same evaluation as other alternatives

Developed by Alex McInturff, Angela Matz, Mitch Eaton, Paul Barrett, Sarah J. Converse

Creative Commons Licenses photos

Case study: (Runge et al. 2011)



Arizona Department of Education

Recall objectives:

Fundamental objectives

- Maximize resources to protect tribal sacred sites and spiritual values
  - Minimize taking of life
- Maximize native species integrity
  - Maximize HBC population
  - Min. trout population
- Maximize recreation
  - Min. wilderness days lost
  - Max. fish catch
- Minimize cost
  - Min. trout removal cost
  - Max. dam power production

Means objectives

Process objectives

- Be respectful of tribal values and rituals

Strategic objectives

-Operate within the authority, capabilities, and legal responsibility of the Bureau of Reclamation

- Follow ESA compliances

Adapted & simplified from Runge et al. 2011

Your task:

Generate alternatives (consider strategies)

University of Missouri

--THEMES--

a) Trout management	b) HBC habitat	c) Recreation
1. None	1. None	1. No changes
2. 25 fish/acre killed	2. Plant native vegetation	2. Remove 50 boating days per year
3. 50 fish/acre killed	3. Build sediment curtain	3. Close wilderness areas for 1 year
4. 25 fish/acre removed via helicopter		4. Prohibit boating for 1 year
5. 50 fish/acre removed via helicopter		

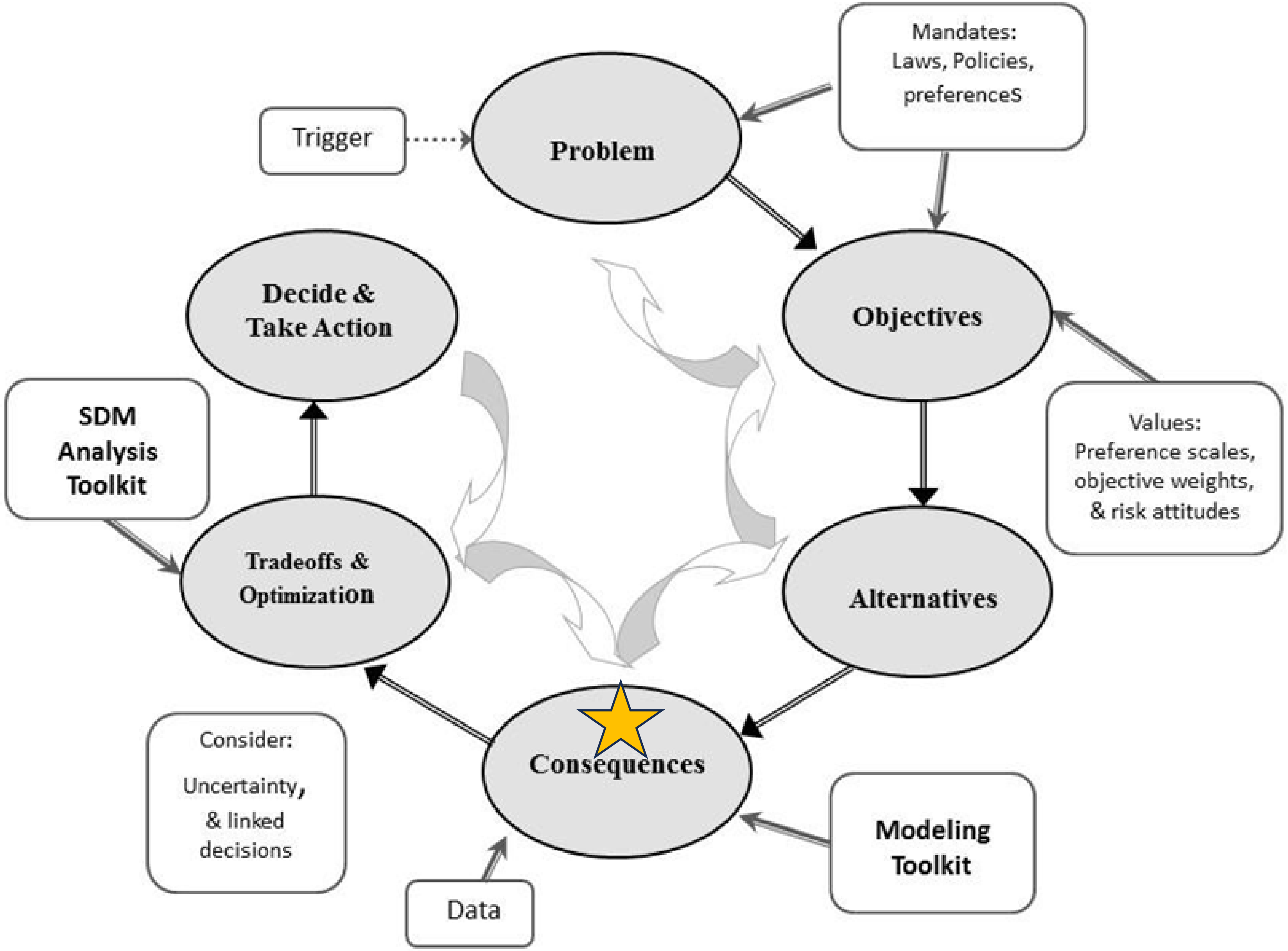
Strategy table:

Strategy	A) Trout management	B) HBC habitat	C) Recreation
A (none)	a1	b1	c1
B	a2	b2, b3	c2
C	a3	b2, b3	c3
D	a4	b2, b3	c4
E	a5	b2	c3, c4

Adapted, modified, and simplified from Runge et al. 2011

University of Missouri

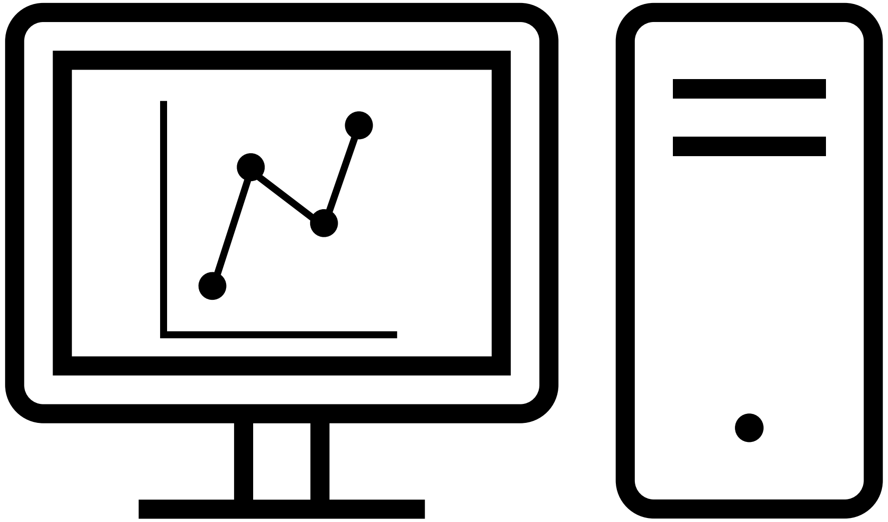
Consequences



Source: Jean Fitts Cochrane

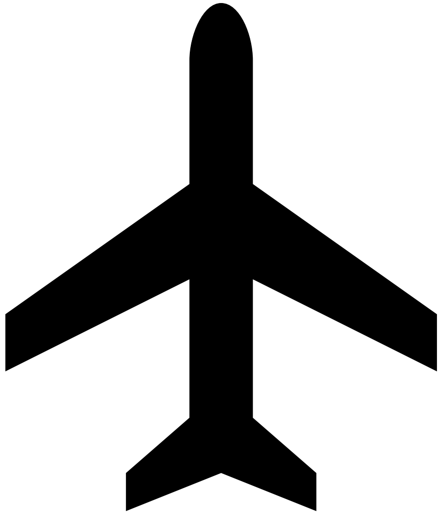
The consequences step

- Consequences link objectives and alternatives
- Models (in SDM) are tools that help us predict consequences
- Not always complex:
  - Will I make an 8:30 meeting if I leave home at 7:45?
    - The model is my experience
    - Or the model is Google maps



Simple example – set up

- I need to arrange a flight
- My objectives are:
  - Minimize price
  - Minimize flight duration
  - Minimize number of stops
  - Arrive before noon
  - Maximize quality of service
- I need to make predictions about each of these objectives
- Source of predictions:
  - Google flights: price, flight time, number of stops, and arrival time
  - TripAdvisor: airline service ratings



Simple example – **consequence table**

Objectives	Attribute	Desired Direction	Alternatives		
			1	2	3
Price	Cost	↓			
Flight time	Duration	↓			
	Number of stops	↓			
Arrive before noon	Arrival time	threshold			
Service	Service rating: 1-5 (# of raters)	↑			

Simple example – **consequence table**

Objectives	Attribute	Desired Direction	Alternatives		
			1	2	3
Price	Cost	↓	$558	$251	$391
Flight time	Duration	↓	3h 40m	5h	5h 47m
	Number of stops	↓	nonstop	1	1
Arrive before noon	Arrival time	threshold	11:11am	4:40pm	10:57am
Service	Service rating: 1-5 (# of raters)	↑	2 (2121 raters)	2 (233 raters)	3 (1875 raters)

Some Principles of Modeling in SDM

Models should

1. Include ‘hard data’ (e.g., total cost) and subjective assessment (e.g., angler satisfaction) as appropriate
2. Make the most of available information, including expert judgment
3. Report appropriate level of precision
4. Incorporate relevant uncertainty
   -Structural (broad model assumptions) e.g., density dependence?
   - Parametric uncertainty e.g., what is the parameter’s distribution?

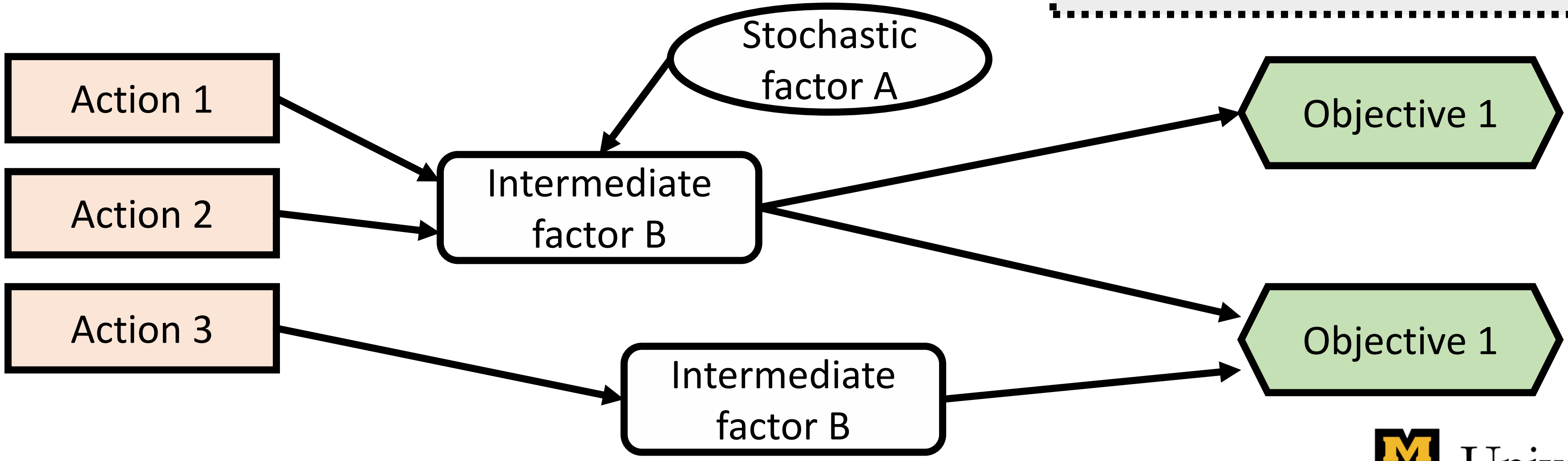
Developed by Sarah J. Converse

Influence Diagrams

- Start with an influence diagram to develop a common understanding of the basic components of a model and the relationships between them

- Influence diagram:
  - Directed Acyclic Graph (DAG)
  - Conceptually link the actions to objectives
  - Distinguish between relationships of the system
  - Begin with objectives and move towards alternatives

- Actions (rectangles)
- Stochastic factors (ovals)
- Intermediate factors (rounded rectangles)
- Objectives (hexagons)

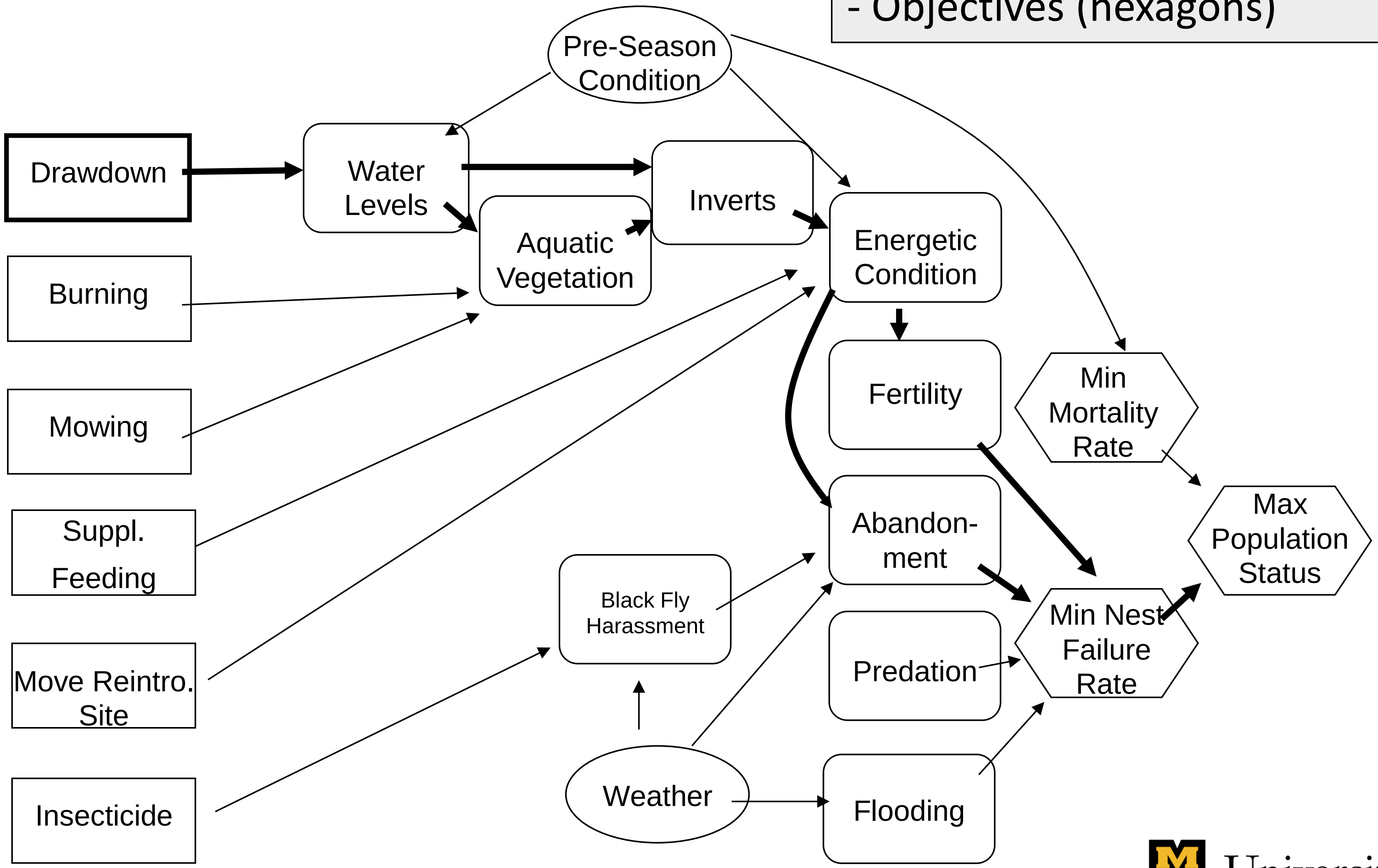


University of Missouri

Developed by Sarah J. Converse

Example: Crane Nest Failure

- Actions (rectangles)
- Stochastic factors (ovals)
- Intermediate factors (rounded rectangles)
- Objectives (hexagons)

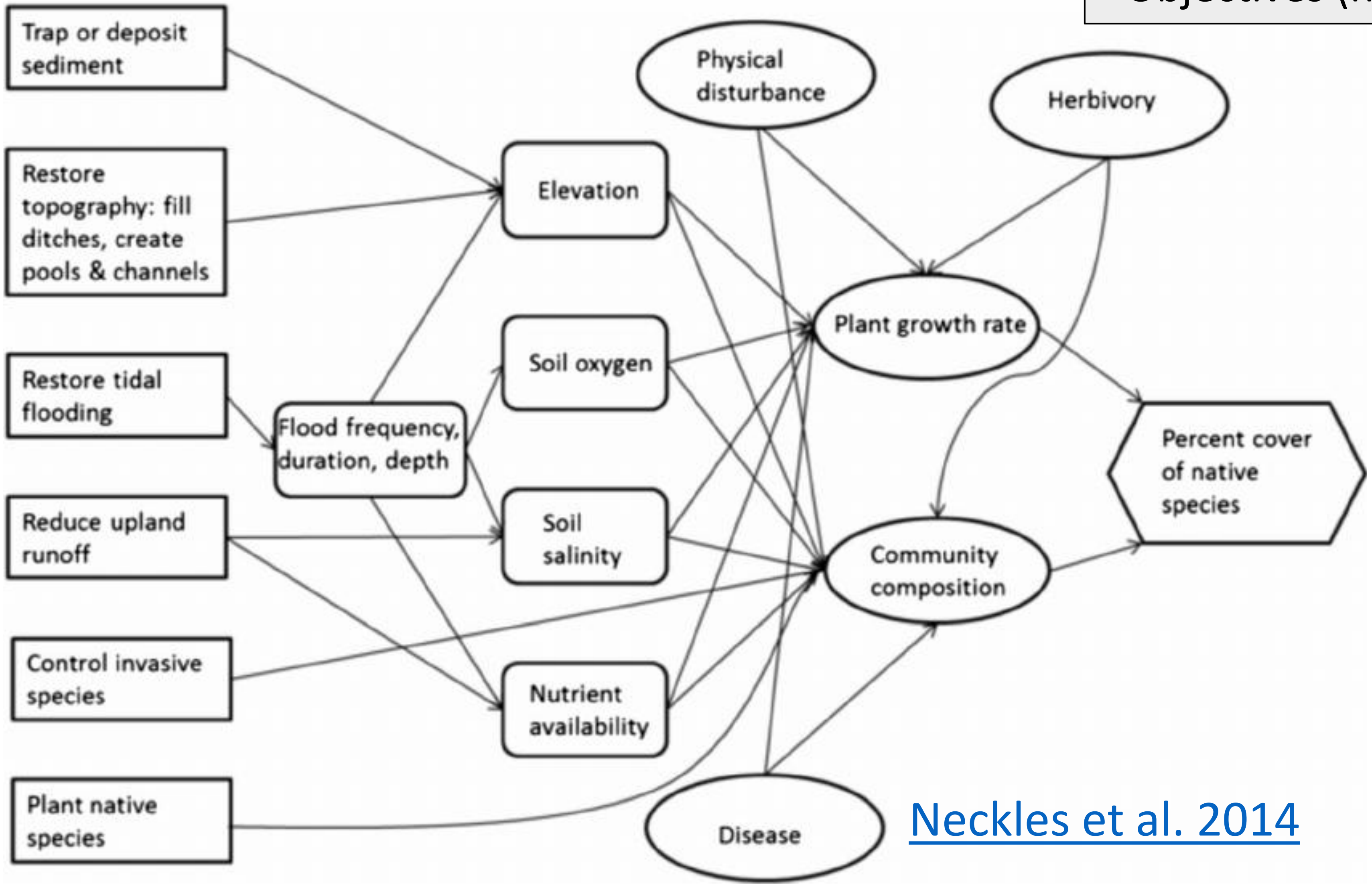


Developed by Sarah J. Converse

University of Missouri

Example: Salt Marsh recovery

- Actions (rectangles)
- Stochastic factors (ovals)
- Intermediate factors (rounded rectangles)
- Objectives (hexagons)



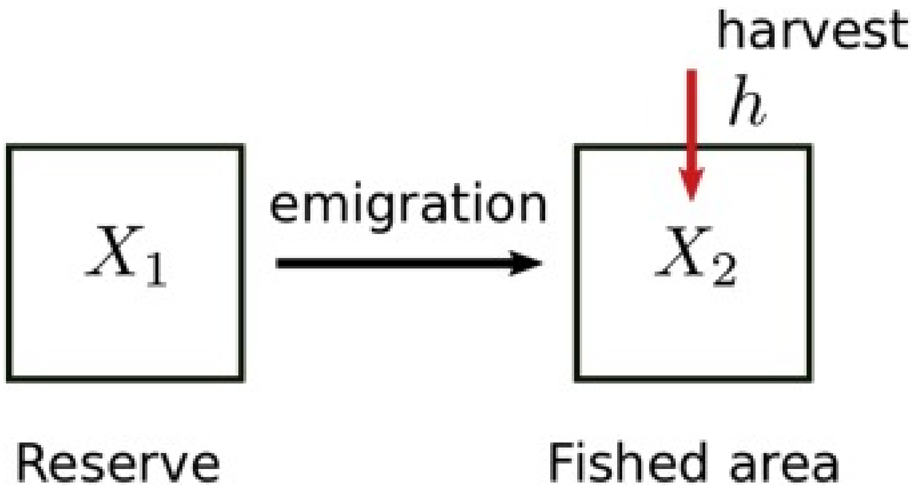
[Neckles et al. 2014](https://doi.org/)

University of Missouri

Developed by Brielle K Thompson

Modeling step

- A variety of models can be used to generate consequences (i.e. results)
- For example:
  - Population models (*most common)
    - Discrete time population models
    - Integrated population models
    - Occupancy models
    - Etc!
  - Statistical models
  - Empirical data
  - Expert opinion/ expert elicitation



da Silveira Costa & dos Anjos 2019

- Conduct rapid prototyping: start simple, adjust, and build up

Consequence table

- Consequence tables = A convenient way to display predictions for multi-objective decisions
  - Matrix of predictions by objective and alternative
  - Can give us an overall sense of our alternatives
  - Facilitates solving multi-objective decisions

	Alternative 1	**Alternative 2**	**…**	**Alternative n**
Objective 1	*prediction*	*prediction*		*prediction*
Objective 2	*prediction*	*prediction*		*prediction*
…				
Objective m	*prediction*	*prediction*		*prediction*

Example: consequence table

Gregory R and Long G. 2009. Using structured decision making to help implement a precautionary approach to endangered species management. Risk Analysis 29:518-532.

Objective	Attribute	Direction	Units	Status Quo	Preservation	Commercial	Terminal Benefits	Spread the Pain 1	Spread the Pain 2	Max Rebuilding	Spread the Pain 3	Sports Compromise
Conservation	% meeting Rec Plan Objective 1	H	%	73%	76%	82%	80%	72%	80%	84%	79%	81%
Conservation	% meeting Rec Plan Objective 2	H	%	32%	33%	33%	34%	31%	35%	34%	33%	34%
Conservation	No of returns in 2010	H	# 000	6.3	7.8	12.5	8.7	6.5	8.6	13.2	8.0	8.9
Conservation	No of returns in 2016-2019 (ave)	H	# 000	16.9	24.3	47.7	31.1	16.8	30.1	53.8	28.7	35.7
Conservation	Probability of extinction	L	%	2.4%	1.1%	0.0%	0.3%	3.4%	0.2%	0.0%	0.4%	0.2%
Conservation	% Enhanced fish 2010	L	%	27%	21%	56%	34%	26%	35%	52%	37%	46%
Conservation	% Enhanced ave fish 2016-2019	L	%	33%	29%	45%	41%	32%	42%	41%	45%	46%
Costs	Total Costs	L	!Yr An Ave $00	$ 171	$ 309	$ 588	$ 488	$ 171	$ 523	$ 588	$ 328	$ 500
Catch	Total Downstream	H	# 000	1,925	304	6,601	3,391	3,391	4,642	1,925	4,618	4,642
Catch	Total Upstream	H	# 000	637	2,884	504	2,365	2,365	2,335	3,054	2,131	2,335
Catch	Total First Nations	H	# 000	777	739	769	796	796	768	797	768	768
Jobs	Total FTEs	H	# FTEs	1.60	2.80	4.10	3.70	1.60	3.30	4.10	2.50	4.10

Example: consequence table

Post van der Burg, M., and M. E. Colvin. 2024. Using structured decision making to assess management alternatives to inform the 2024 update of the Minnesota Invasive Carp Action Plan. Report 2024-1020, Reston, VA.
https://pubs.usgs.gov/publication/ofr20241020

Objective	Mean weight	Strategy																	
		1	8	12	5	7	6	9	10	2	4	18	13	17	16	14	15	3	11 (optimal strategy)
Decrease invasive carp abundance	0.13	1.75[a]	6.31	3.84	5.56	6.25	5.28	4.94	5.94	3.44	4.63	7.69	6.22	8.23	6.94	6.38	7.13	8.63[b]	6.56
Minimize negative effects on native mussels	0.07	4.38[a]	6.50	7.13	6.75	7.38	6.56	6.00	6.69	5.19	6.56	7.38	7.13	7.63	6.97	7.50	6.94	8.50[b]	6.88
Minimize effects to native fish	0.13	3.63[a]	5.56	6.50	5.50	5.81	5.44	5.38	5.75	4.44	5.41	6.56	6.22	6.69	6.34	6.56	6.44	7.38[b]	6.31
Minimize effects to native flora	0.07	6.25[a]	6.81	7.81	6.56	6.88	7.06	6.88	7.22	6.69	6.56	7.63	7.56	7.72	7.72	7.44	7.84	8.19[b]	7.56
Maintain recre-ational opportu-nities	0.09	4.00[a]	5.38	5.03	5.03	5.50	5.34	5.63	5.38	5.41	5.88	6.56	7.09	6.69	6.81	6.81	6.81	7.48[b]	6.50
Minimize nega-tive effects to Minnesota river-based economies	0.07	3.75[a]	6.63	5.22	5.56	6.38	5.47	5.81	6.38	5.03	5.19	7.25	7.16	6.94	6.75	6.13	6.63	8.48[b]	6.75
Minimize carp threats to public safety	0.08	4.00[a]	6.44	4.97	5.91	6.19	6.16	6.00	6.63	5.16	5.56	7.88	6.91	7.75	7.13	6.88	7.13	8.04[b]	6.75
Minimize manage-ment threats to public safety	0.07	9.25[b]	7.63	8.13	7.50	7.50	7.75	7.75	7.50	8.88	8.25	7.38	8.50	7.50	7.38	7.69	7.50	5.94[a]	8.25
Minimize negative effect to cultural practices	0.07	5.63[a]	6.75	5.81	6.75	7.13	7.13	6.88	6.94	7.25	7.25	6.88	7.38[b]	7.00	7.13	7.38[b]	7.13	7.38[b]	7.00
Maintain access for underserved populations	0.06	7.13[a]	8.00	7.91	8.31	8.25	8.50	8.44	8.50	8.38	8.75[b]	8.13	8.63	8.25	8.50	8.25	8.63	8.38	8.50
Minimize preven-tion and control costs of the action	0.07	8.75[b]	2.25	5.57	4.44	2.00	4.13	5.56	3.16	7.81	6.50	1.64	4.38	1.64	3.29	5.07	3.29	0.50[a]	5.21
Minimize imple-mentation time	0.10	10.00[b]	2.31	3.81	3.63	2.13	3.31	3.56	2.88	10.00[b]	6.75	2.13	2.38	2.00	4.13	3.88	4.44	1.13[a]	7.13
Total score	--	**5.41**	**5.75**	**5.76**	**5.79**	**5.81**	**5.81**	**5.85**	**5.91**	**6.22**	**6.23**	**6.36**	**6.44**	**6.46**	**6.50**	**6.54**	**6.58**	**6.66**	**6.86**

[a]Maximum score of an objective (shaded yellow).

[b]Minimum score of an objective (shaded red).

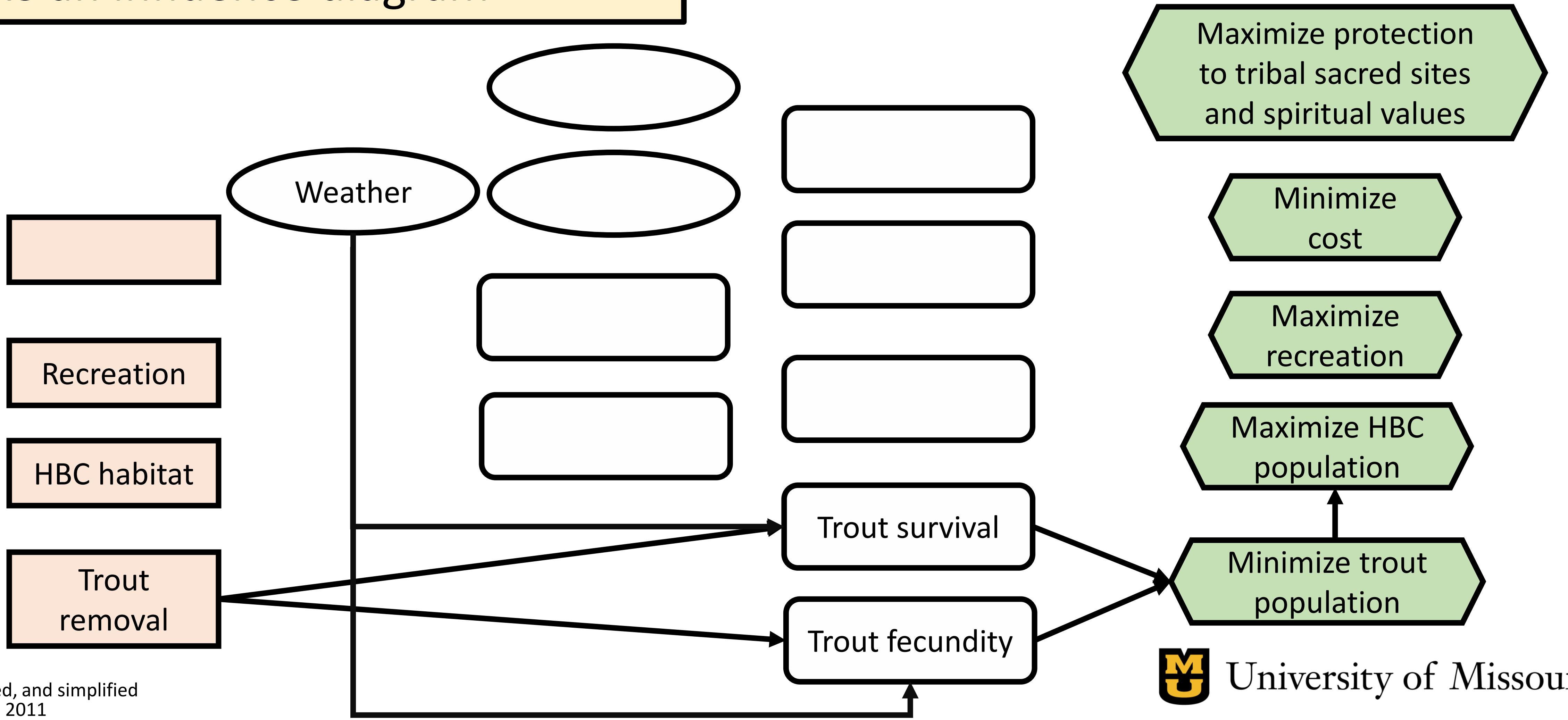
University of Missouri

Developed by Mike Colvin

Case study: (Runge et al. 2011)

- Actions (rectangles)
- Stochastic factors (ovals)
- Intermediate factors (rounded rectangles)
- Objectives (hexagons)

Your task: Consequences step
Make an influence diagram

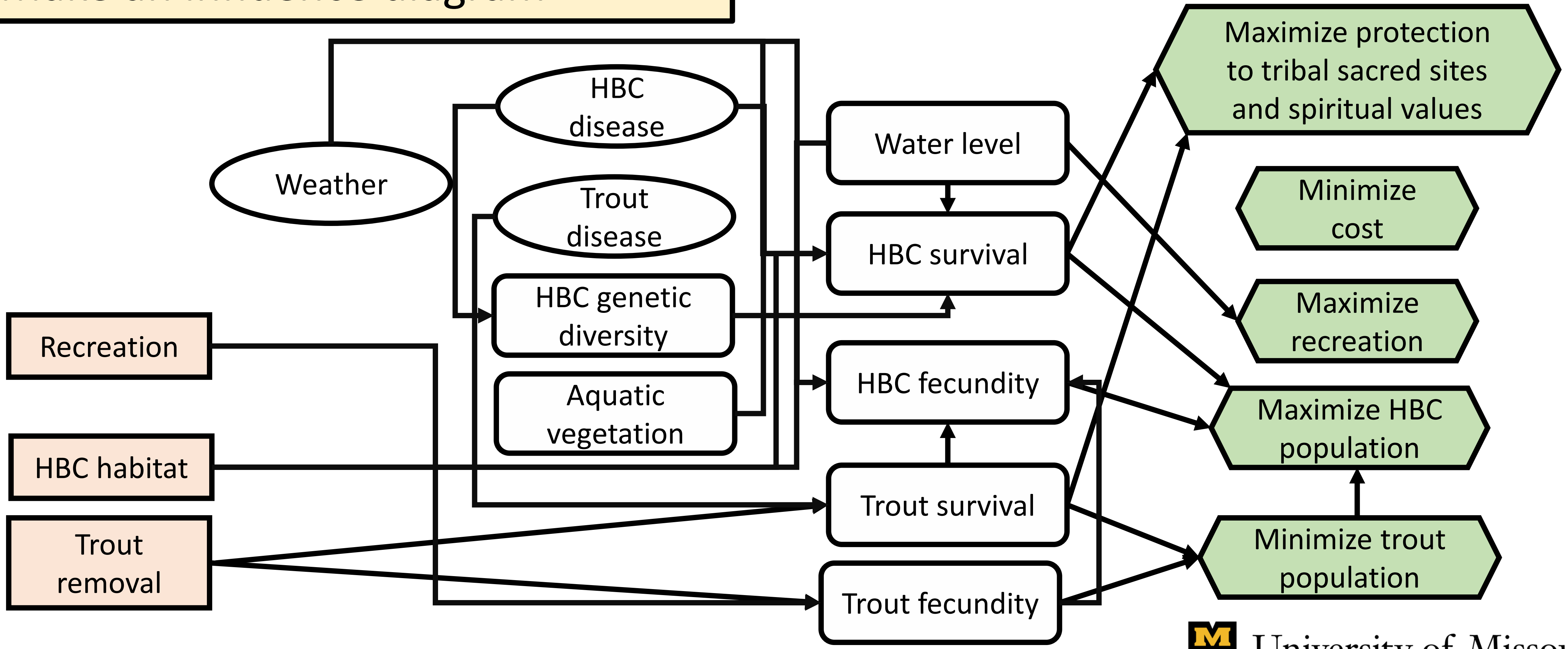


Adapted, modified, and simplified from Runge et al. 2011

Case study: (Runge et al. 2011)

- Actions (rectangles)
- Stochastic factors (ovals)
- Intermediate factors (rounded rectangles)
- Objectives (hexagons)

Your task: Consequences step
Make an influence diagram



Adapted, modified, and simplified from Runge et al. 2011

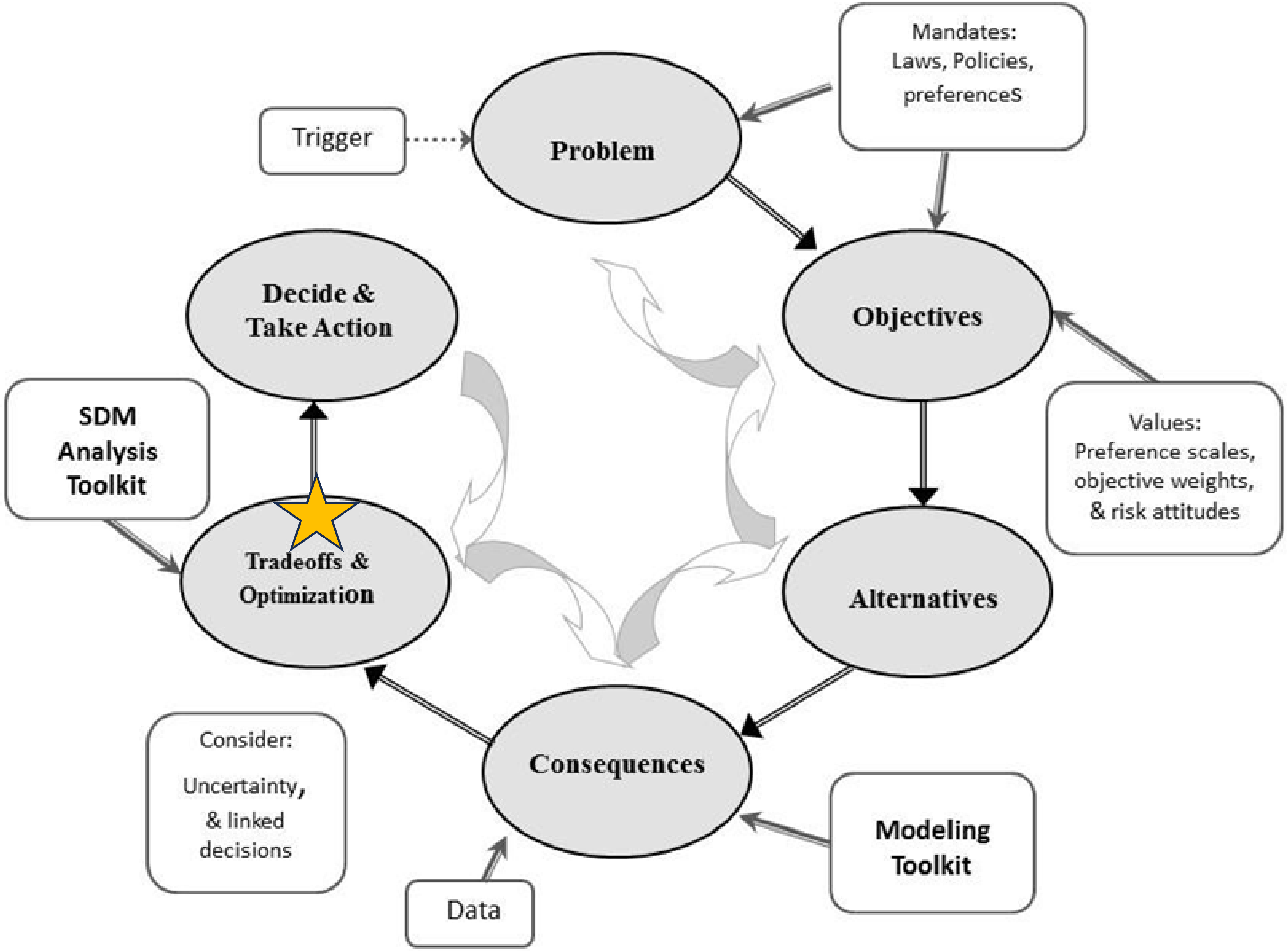
Case study: (Runge et al. 2011)

Look at the potential consequence table

MODEL:	Objective			Alternative				
	Objective	Direction	Attribute	A	B	C	D	E
Expert elicitation	**Respect Life**	Max	[0-10 scale]	**6**	**7**	**6**	**9.5**	**9**
Population model	**HBC Recovery**	Max	[P(N>6000)]	**0.2**	**0.3**	**0.3**	**0.3**	**0.25**
Expert elicitation/ population model	**Wilderness Disturbance**	Min	[User-days]	**0**	**30**	**40**	**50**	**60**
	Cost	Min	[M$/5-yr]	**0**	**2.5**	**3**	**4.5**	**2**

The consequence table was inspired by Runge et al. 2011
but the values in the table were altered for simplicity

Tradeoffs



Source: Jean Fitts Cochrane

Tradeoffs

"How much you would give up on one objective in order to achieve gains on another objective"

- Gregory et al. 2012

Role of analytical methods in tradeoff analysis

- Identify “best” (optimal) solution
  - Ties together alternatives, objectives, and predicted consequences
- Easiest with a single objective
- Easiest without uncertainty

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

Analytical approaches

	Approach
Single Objective	• Deterministic optimization
Multiple Objectives	• Multiple Attribute Utility • Simplification • SMART • Pareto frontier analysis
	Negotiate among most efficient alternatives

Increased complexity

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

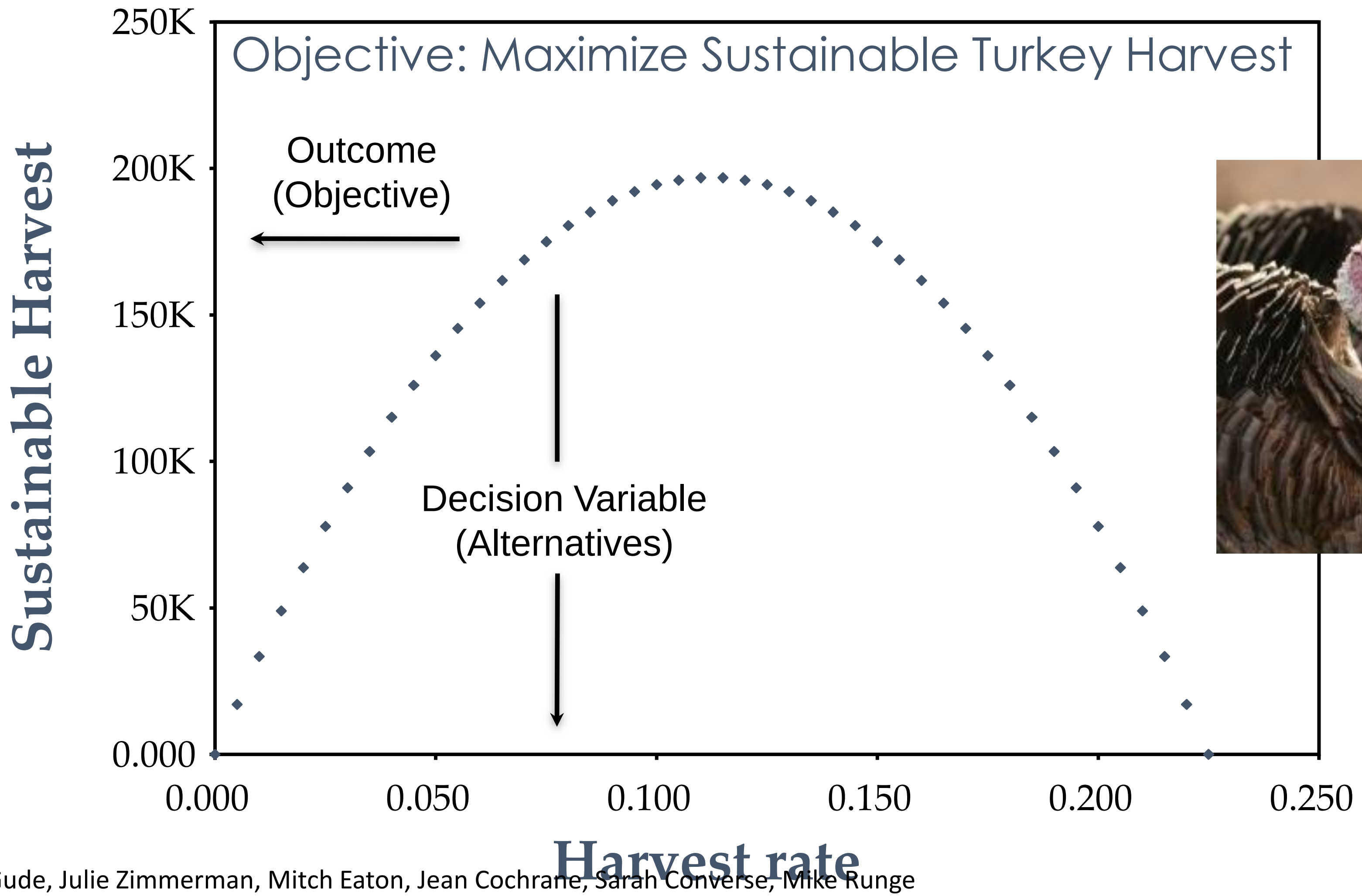
Single objective approach:

- Used when we have a continuous decision variable (i.e., alternatives)
  - e.g., harvest rate, amount of herbicide to apply, size of biocontrol release, etc.
- & Objective is a function of the decision variable
- Optimization solution methods:
  - Graphical
  - Closed-formed solutions (calculus/differentiation)
  - Numerical solutions (mathematical search methods)
  - Constrained optimization (mathematical solution)

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

Single objective approach:

- Graphical optimization:



University of Missouri

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

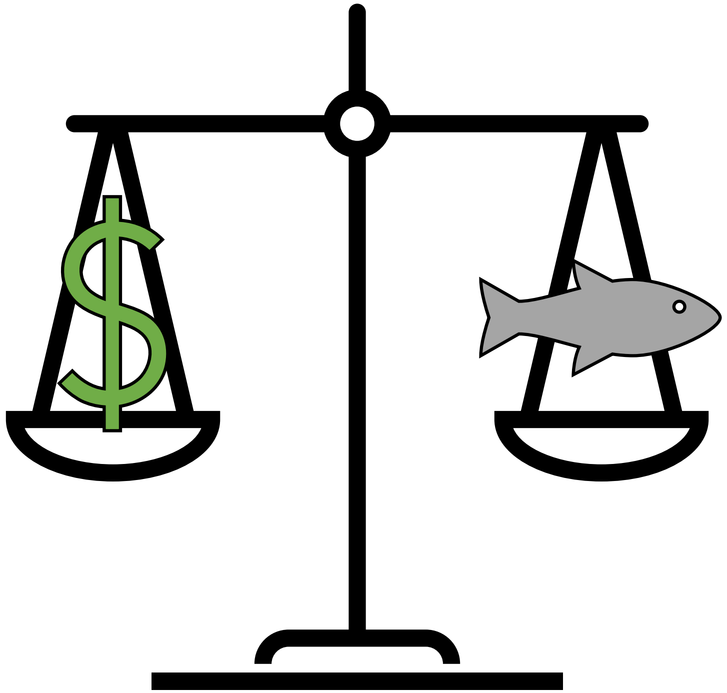
Single objective approach:

Question: Can you think of an example of a single objective problem?

- Not very common in natural resource management.
- Single objectives are easier to optimize, so we may want to reduce multiple objective problems to make them easier to solve.

Multiple objective tools

- Nearly all natural resource management problems are multiple-objective problems



University of Missouri

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

A. Simplify the problem

1. Remove dominated alternatives:

- i.e., another alternative performs the same or better on all objectives

A. Simplify the problem (EXAMPLE)

1. Remove dominated alternatives (another alternative performs the same or better on all objectives)

Objectives	Direction	Alternatives			
		Status quo	Minor repair	Major repair	Re-build
Cost ($M)	Min				
Environmental Benefit (0-10)	Max				
Disturbance (0-10)	Min				
Silt runoff (k ft^3)	Min				
Water Retention (MG)	Max				

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

A. Simplify the problem (EXAMPLE)

1. Remove dominated alternatives (another alternative performs the same or better on all objectives)

Objectives	Direction	Alternatives			
		Status quo	Minor repair	Major repair	Re-build
Cost ($M)	Min	0	2	12	20
Environmental Benefit (0-10)	Max	1	3	10	10
Disturbance (0-10)	Min	0	1	7	10
Silt runoff (k ft^3)	Min	5	1	3	3
Water Retention (MG)	Max	41	41	41	39

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

A. Simplify the problem (EXAMPLE)

1. Remove dominated alternatives (another alternative performs the same or better on all objectives)

Objectives	Direction	Alternatives			Dominated Alternative
		Status quo	Minor repair	Major repair	Re-build
Cost ($M)	Min	0	2	12	20
Environmental Benefit (0-10)	Max	1	3	10	10
Disturbance (0-10)	Min	0	1	7	10
Silt runoff (k ft^3)	Min	5	1	3	3
Water Retention (MG)	Max	41	41	41	39

A. Simplify the problem

1. Remove dominated alternatives:
    - i.e., another alternative performs the same or better on all objectives

2. Remove irrelevant objectives:
- i.e., performance measures of that objective does not vary over alternatives
- This isn't to say the objective isn't important to you, just that it doesn't help discern among the alternatives <u>currently considered.</u>

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

A. Simplify the problem (EXAMPLE)

2. Remove irrelevant objective

Objectives	Direction	Alternatives			
		Status quo	Minor repair	Major repair	Re-build
Cost ($M)	Min	0	2	12	20
Environmental Benefit (0-10)	Max	1	3	10	10
Disturbance (0-10)	Min	0	1	7	10
Silt runoff (k ft^3)	Min	5	1	3	3
Water Retention (MG)	Max	41	41	41	39

Dominated Alternative

A. Simplify the problem (EXAMPLE)

2. Remove irrelevant objective

Objectives	Direction	Alternatives			
		Status quo	Minor repair	Major repair	Re-build
Cost ($M)	Min	0	2	12	20
Environmental Benefit (0-10)	Max	1	3	10	10
Disturbance (0-10)	Min	0	1	7	10
Silt runoff (k ft^3)	Min	5	1	3	3
Water Retention (MG)	Max	41	41	41	39

Dominated Alternative

Irrelevant Objective

A. Simplify the problem (EXAMPLE)

- **Simplified problem:**

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
Cost ($M)	Min	0	2	12
Environmental Benefit (0-10)	Max	1	3	10
Disturbance (0-10)	Min	0	1	7
Silt runoff (k ft^3)	Min	5	1	3

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

A. Simplify the problem

1. Remove dominated alternatives:
   - i.e., another alternative performs the same or better on all objectives

2. Remove irrelevant objectives:
   - i.e., performance measures of that objective does not vary over alternatives
   - This isn't to say the objective isn't important to you, just that it doesn't help discern among the alternatives <u>currently considered.</u>

3. Make even swaps:
   - If two objectives are in the same unit, then combine outcomes

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

A. Simplify the problem (EXAMPLE)

3. Even swaps

Convert silt runoff to cost @ $0.5M / k ft^3

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
Cost ($M)	Min	0	2	12
Environmental Benefit (0-10)	Max	1	3	10
Disturbance (0-10)	Min	0	1	7
Silt runoff (k ft^3)	Min	5	1	3

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

A. Simplify the problem (EXAMPLE)

3. Even swaps

Convert silt runoff to cost @ \$0.5M / k ft^3

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
Cost (\$M)	Min	0	2	12
Environmental Benefit (0-10)	Max	1	3	10
Disturbance (0-10)	Min	0	1	7
Silt runoff (k ft^3)	Min	~~5~~ 2.5 M	~~1~~ 0.5 M	~~3~~ 1.5 M

University of Missouri

A. Simplify the problem (EXAMPLE)

3. Even swaps

Convert silt runoff to cost @ $0.5M / k ft^3

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
Cost ($M)	Min	0 + 2.5	2 + 0.5	12 + 1.5
Environmental Benefit (0-10)	Max	1	3	10
Disturbance (0-10)	Min	0	1	7
Silt runoff (k ft^3)	[redacted]			

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

B. Reduce to a single objective

- Tip: Convert all objectives but one to constraints
  - Example: don't spend more than $2.5M
  - Keep disturbance at or below 3
  - Then take the maximum environmental benefit

Objectives	Direction	Alternatives		
		Status quo	Minor repair	Major repair
Cost ($M)	Min	2.5	2.5	13.5
Environmental Benefit (0-10)	Max	1	3	10
Disturbance (0-10)	Min	0	1	7

University of Missouri

Multiple objective tools

A. Simplify the problem

1. Remove dominated alternatives:

2. Remove irrelevant objectives

3. Make even swaps

B. Reduce to a single objective

C. Negotiate a solution from a set of best compromises *(What are we willing to tradeoff?)*

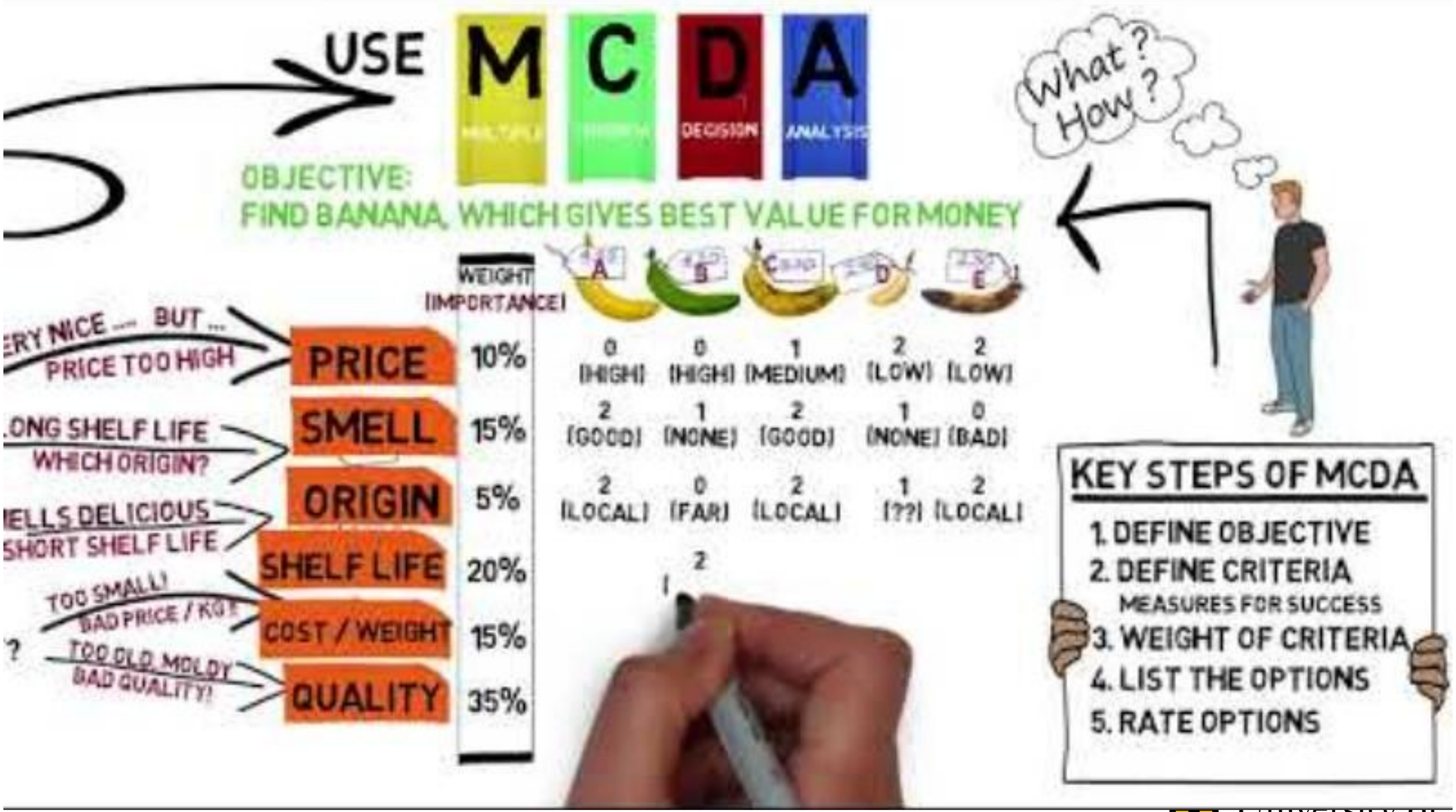
D. Evaluate tradeoffs explicitly

Developed by Justin Gude, Julie Zimmerman, Mitch Eaton, Jean Cochrane, Sarah Converse, Mike Runge

D. Evaluate trade-offs explicitly

- Multicriteria decision analysis (MCDA)
  - Tools to evaluate multiple objective problems
- Example tools: *(**beyond the scope of this workshop**)*
  - Outranking methods
  - Analytic Hierarchy Process
  - Multi-attribute value/utility theory
  - SMART (simple multi-attribute rating technique)

3-minute intro to MCDA



Simple multi-attribute rating technique (SMART) –type of MCDA tool

1. Define objectives
2. Assign weights (w_i) for each objective (weights should sum to 1)
3. Normalize attributes (x_i) to a 0 to 1 scale for each objective
4. Calculate weighted average total score (S_a) for each alternative

$$\text{total score for alternative } a = S_a = \sum_{i=1}^{\#\, of\ objectives} w_i x_i$$

5. Identify the alternative with the highest total score

University of Missouri

Developed by Sarah Converse, Brielle Thompson

Case study: (Runge et al. 2011)

Are there irrelevant objectives, dominated outcomes, even swaps?

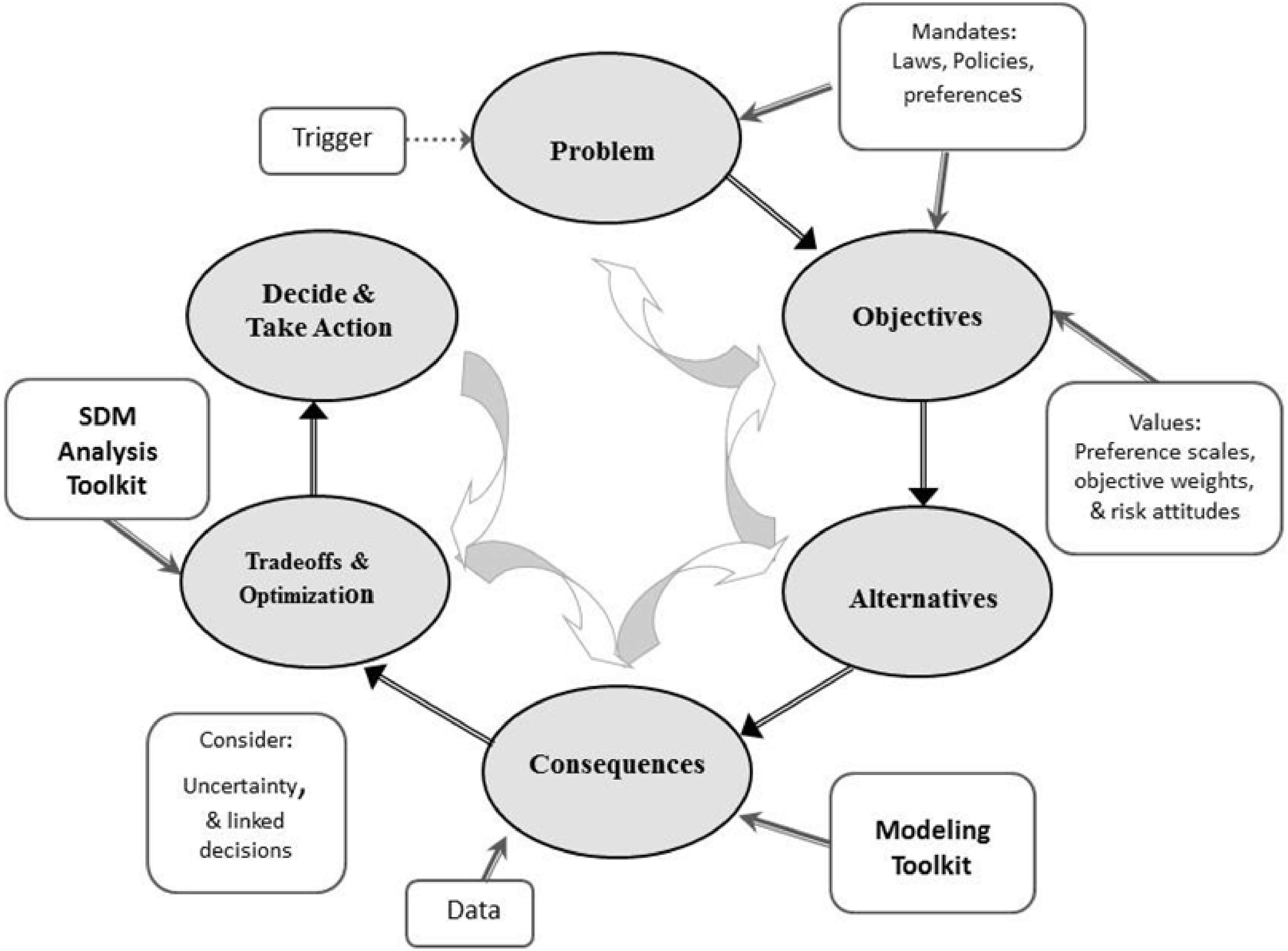
Your task: Evaluate tradeoffs

Objective			**Alternative**				
Objective	Direction	Attribute	A	B	C	D	E
Respect Life	Max	[0-10 scale]	**6**	**7**	**6**	**9.5**	**9**
HBC Recovery	Max	[P(N>6000)]	**0.2**	**0.3**	**0.3**	**0.3**	**0.25**
Wilderness Disturbance	Min	[User-days]	**0**	**30**	**40**	**50**	**60**
Cost	Min	[M$/5-yr]	**0**	**2.5**	**3**	**4.5**	**2**

The consequence table was inspired by Runge et al. 2011 but the values in the table were altered for simplicity

University of Missouri

Concluding thoughts



Source: Jean Fitts Cochrane

University of Missouri

Developed by Ashley Fortune Isham, Jim Lyons, Sarah J Converse

Summary:

Two key elements of Structured Decision Making

1. Values-focused

- Objectives are discussed first
- Contrasts with alternative-focused methods

2. Problem decomposition

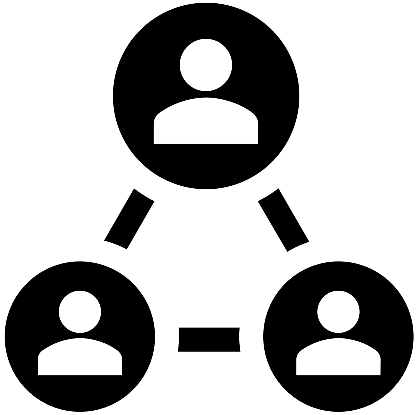
- Break problem into components, separating science from values
- Complete relevant analysis
- Recompose the parts to make a decision
- PrOACT

University of Missouri

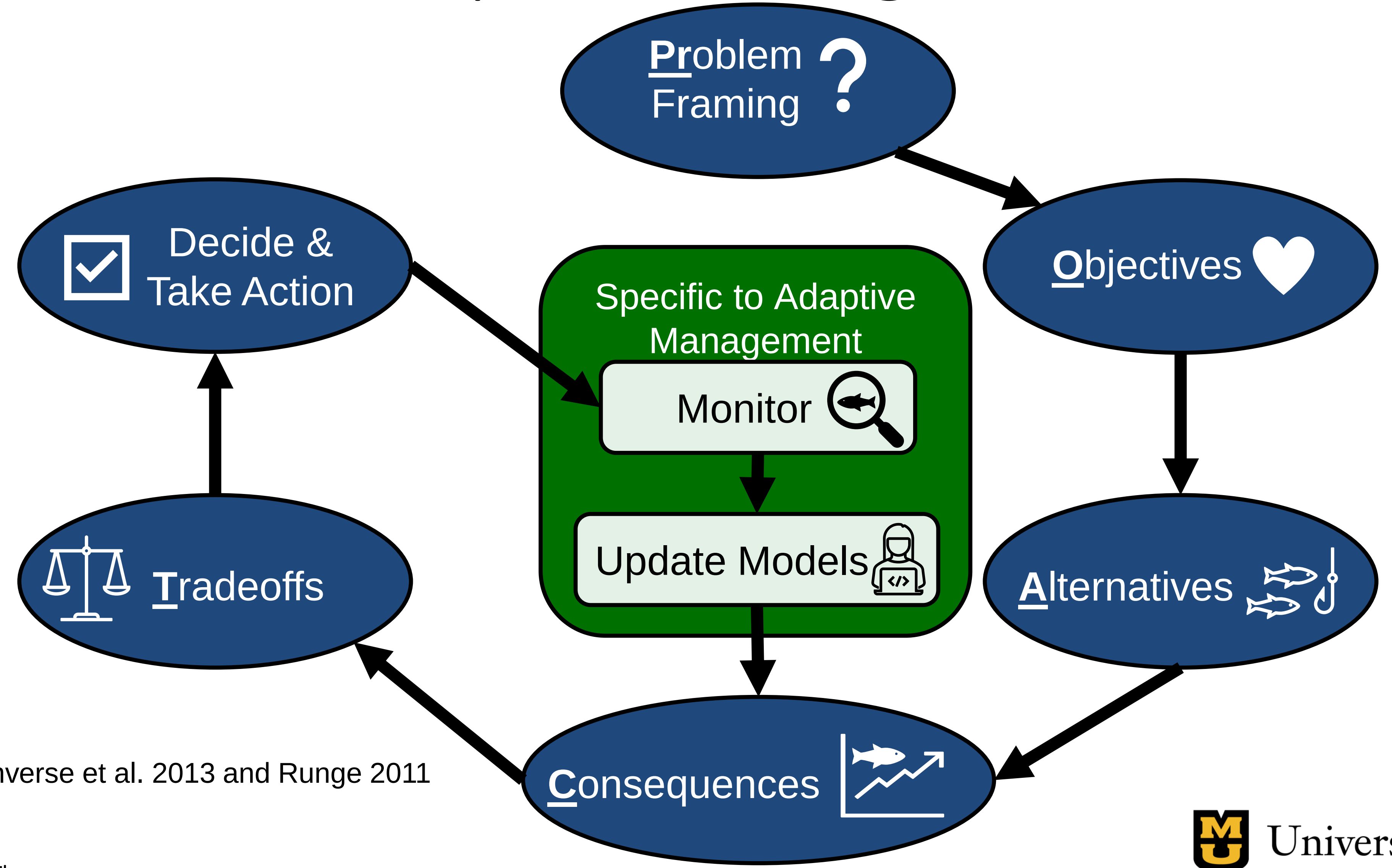
Developed by Ashley Fortune Isham, Jim Lyons, Sarah J Converse

What else?

- What we didn't cover:
  - **Dealing with uncertainty**
    - Simulations, sensitivity analysis
    - Risk analysis
    - Value of information analysis
      - Determines the "value" of collecting additional information
    - Adaptive management
  - **Dealing with people**
    - Stakeholder analysis, forming a team
    - Facilitation
    - Expert elicitation



An aside on adaptive management



Adapted from Converse et al. 2013 and Runge 2011

University of Missouri

Developed by Brielle K Thompson

An aside on adaptive management

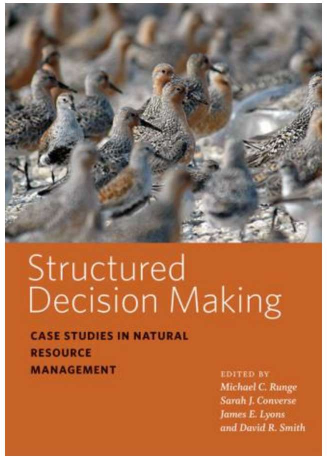
- What it is:
  - **Iterative** decision process of "**learning by doing**" that uses **monitoring data** to **reduce uncertainty** and **adapt** management over time
- What it is not:
  - Trial by error
- We can use it when we have:
  - Repeated decisions
  - Uncertainty that is important to management
  - The ability to monitor to reduce uncertainty
- Analytical tools:
  - Management Strategy Evaluation
  - Stochastic Dynamic Programming
  - Bayesian updating

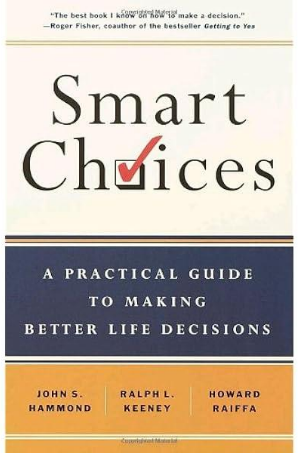
Waterfowl harvests
(Williams and Johnson 1995)

30 years + counting!

Additional Resources

- Peer reviewed journal articles/books/videos
    - Structured Decision Making Book (Runge et al. 2020)
    - Review paper: An introduction to decision science for conservation (Hemming et al. 2022)
    - Smart choices book
    - National Conservation Training Center Videos
    - https://www.structureddecisionmaking.org/resources/



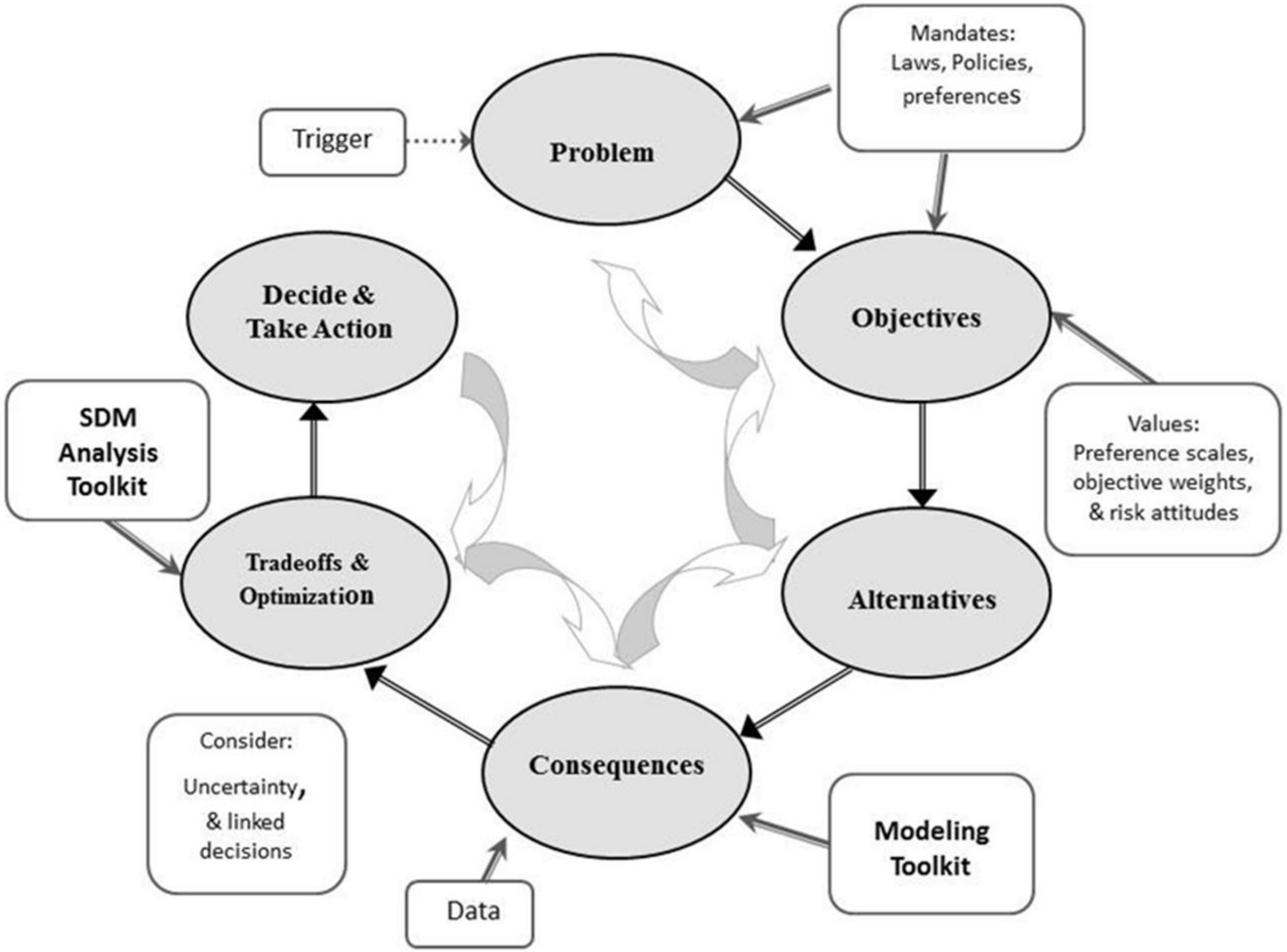


If interested in decision theory:

- *Thinking, Fast and Slow* by Daniel Kahneman
- *Nudge* by Richard Thaler and Cass Sunstein
- *Thinking in Bets* & *Quit* by Annie Duke

Big takeaways

- Two components of SDM
  - Values focused
  - Problem decomposition (PrOACT)
- Rapid prototype and iterative process!



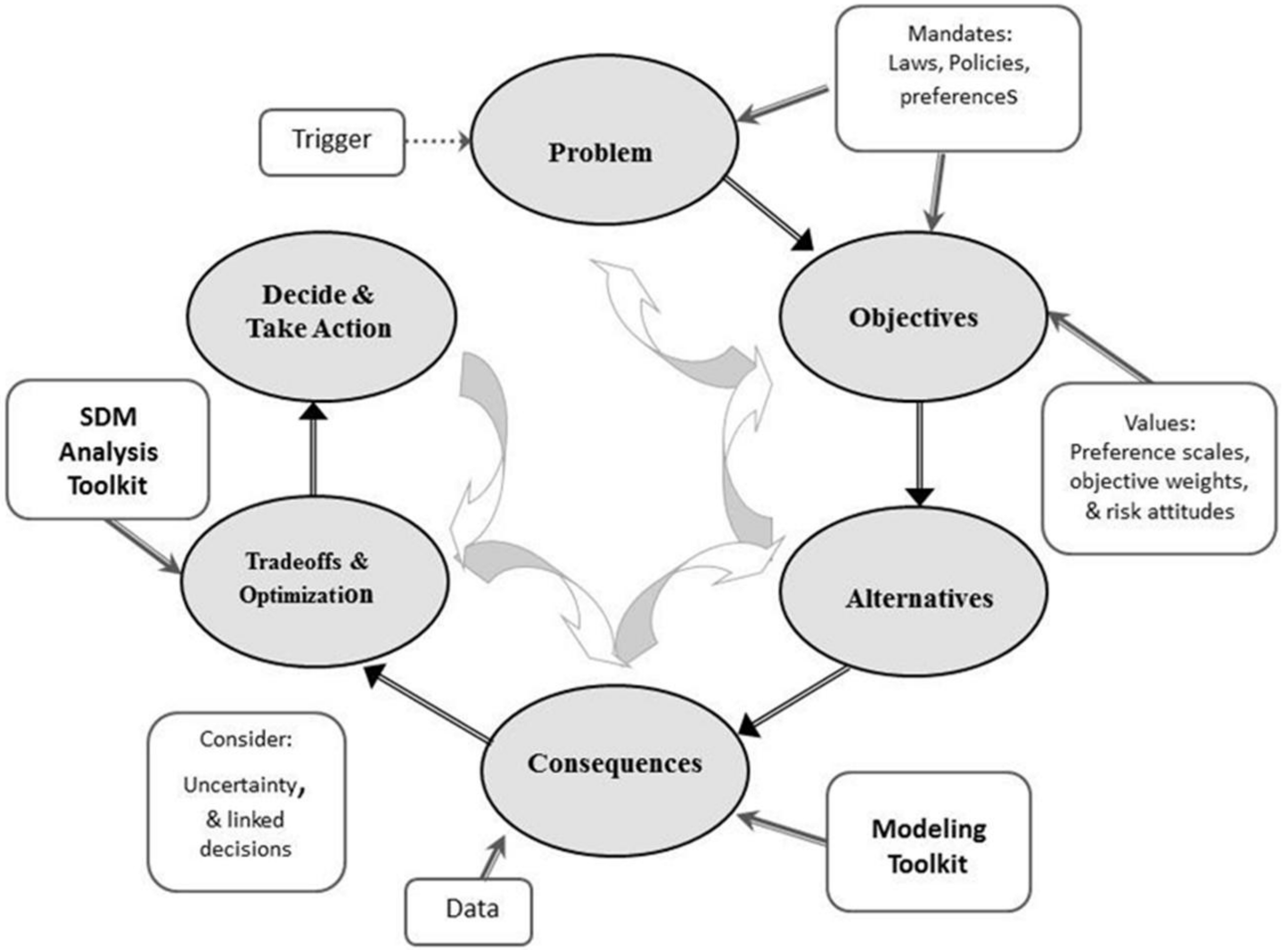
Source: Jean Fitts Cochrane

Discussion

- How would you use SDM in your research?
- Personal life?

- Think about a decision you recently made, which part of PrOACT do you think was the most challenging? Easiest?
- Did you learn anything today that would've helped that decision?

Questions and Comments?



Source: Jean Fitts Cochrane

Workshop Website

Contact:

Brielle K Thompson:

brielle.thompson@missouri.edu

University of Missouri